...ent of Mining Impacts ... Surface Waters in the

FLINT CREEK RANGE

Montana

WATER QUALITY BUREAU
ENVIRONMENTAL SCIENCES DIVISION
MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES
HELENA

SEPTEMBER, 1979

AN ASSESSMENT OF MINING IMPACTS ON QUALITY OF SURFACE WATERS IN THE FLINT CREEK RANGE, MONTANA

Prepared for:

STATEWIDE SECTION 208

WATER QUALITY MANAGEMENT PLANNING

LAND USE/WATER QUALITY RELATIONSHIPS

By:

GARY L. INGMAN
and
LOREN L. BAHLS

WATER QUALITY BUREAU

ENVIRONMENTAL SCIENCES DIVISION

MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES

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Abstract

Investigations of mining-related impacts on streams draining the Flint Creek Range of western Montana were conducted from July through September, 1978. Chemical, physical and biological analyses performed at 51 stations on 37 streams indicated that water quality and the biological health were generally good. Mining activities in the range have impacted a small percentage of the surface waters examined. Severely impacted stream segments were rare. Most of the streams examined had good to excellent quality, cold, highly oxygenated and slightly alkaline waters with low to moderate total dissolved solids, low concentrations of heavy metals and suspended solids and an abundance and diversity of aquatic plants and animals.

Although the number of unquestionably stressed streams was low, the impacted stream stations that were identified could usually be related to effects of mining activity. Conversely, streams showing the highest water quality usually occurred in areas of minimal prospecting. Two streams, the North Fork of Douglas Creek and another Douglas Creek in the Philipsburg area, were severely stressed. In both cases, degradation of water quality resulted from creek waters contacting tailings dumps and was expressed in the form of elevated sulfate, cadmium, copper, iron and zinc concentrations and a severe reduction in numbers and kinds of aquatic organisms. Reclamation was not recommended due to the extreme cost, the small size of the streams and the localized nature of the impacts. Other stations found to be impacted less extensively by mining activity were degraded with metals and sediment. Additionally, in several locations potential erosion and sedimentation problems were associated with placer mine tailings.

Several streams of the range exhibited elevated total phosphorus concentrations, which were believed to be a result of phosphate deposits in the drainage.

Recommendations were given for prevention of mining-related water quality degradation stemming from the inevitable future development of mineral resources in the Flint Creek Range. Additional water quality data available to date for streams of the range were tabulated.

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Table of Contents

List of Figures

List of Tables

I. INTRODUCTION

The Flint Creek mountain range of western Montana has been identified as an area of intense mining activity, both past and present. The drainage basin of the Upper Clark Fork of the Columbia River, which includes the Flint Creek Range, is highly mineralized. It has the greatest number of hard rock mining permits (seven) and the most identified mining-related water quality problems in the state, excluding those associated with placer mining (Schmidt and Botz, 1978). The basin includes the extensive Anaconda Company operations, the Black Pine Mine, at least four silica or limestone mines, one major gold placer operation and over 100 small miner operations. Exploration activity is significant in both the Flint Creek Range (J. Burke, personal communication) and the Boulder Batholith areas of the basin (R. Pedersen, personal communication). Phosphate reserves are extensive in both the Garnet and Flint Creek Ranges and applications for oil and gas leases have been received for most of the Flint Creek Range (Schmidt and Botz, 1978). The potential for development of future mining in the Flint Creek Range has been demonstrated in the form of phosphate reserves, exploration and applications for oil and gas leasing. Increasing metals prices undoubtedly will cause renewed interest and development in the area.

Water quality impacts resulting from historic mining activity in the Upper Clark Fork River proper have been extensively examined and are under continuing investigation. Mining-related problems within the Boulder Batholith were studied in 1977 (R. Pedersen, Water Quality Bureau). Since comprehensive water quality data on the Flint Creek Range drainages were scanty, and documentation of existing

mining-related problems was lacking, the Water Quality Bureau proposed in 1978 to study the range. The objective of the investigation was two-fold: 1) To establish baseline (or normal background) water quality of drainages originating in the Flint Creek Range; and 2) to identify existing and potential sources of mining-related water quality degradation. The need for and feasibility of abatement of these problems would also be considered. From this information, a perspective of the overall impact of mining on water quality in the Flint Creek Range could be obtained for use in future water quality management. Documentation of existing water quality would allow resource managers to distinguish and control water pollution resulting from future activities in the range.

II. DESCRIPTION OF THE STUDY AREA

A) PHYSICAL SETTING

The Flint Creek Range encompasses approximately 400 square miles in portions of Deer Lodge, Granite and Powell Counties in western Montana. This rugged, mountainous area is bordered on the east and north by the Clark Fork River and on the west by Flint Creek, a north-flowing tributary of the Clark Fork. Elevations vary from an average of about 5,000 feet at the eastern and western flanks to between 8,000 and 9,000 feet at the summit of the range. Some areas exceed 10,000 feet. Topography is diverse, ranging from glacially-carved peaks, cirques, and deep canyons in the central and southern portions to more mature, rounded hills rising gently from the Clark Fork River at the nortnern extreme.

Most of the area is heavily timbered, primarily with species of pine and fir, but with some broadleaf trees. Elevations greater than 8,000 feet are generally free of forest cover. Parks of bunch grass and other forage plants are relatively common

on broad ridges and south-facing slopes.

Parts of the range are remote and accessible only by foot or horse travel but most of it can be reached by four-wheel drive. The roads and jeep trails generally parallel stream drainages and are a result of mining, mineral exploration and timber harvesting over the years.

B) WATER RESOURCES

Streams draining the Flint Creek Range are numerous and generally small. Most are clear, cold and cascading mountain streams with steep gradients until they spill out onto the valley floor.

Stream flows are subject to extreme seasonal variation, occasionally reaching flood proportions in the spring due to heavy snowpack, thin mountain soils and a predominance of relatively impervious granitic rock. Some drainages may go dry entirely in late summer and winter. Major and minor streams of the range are depicted in Figure 1.

Surface water use within the range is primarily recreational. However, most of the drainages are important sources of irrigation water for agriculture in the lowland regions. In addition, the North Fork of Flint Creek and Warm Springs Creek, including its tributaries, supply water for Anaconda Company operations. Tin Cup Joe Creek and Fred Burr Lake supply excellent quality municipal water to the towns of Deer Lodge and Philipsburg, respectively. Mountain lakes are abundant in the range, especially in the headwaters regions of many of the creeks. Several of these have been dammed artifically to maintain irrigation water supplies.

C) GEOLOGICAL RESOURCES

The Flint Creek Range is composed mostly of complexly folded Precambrian

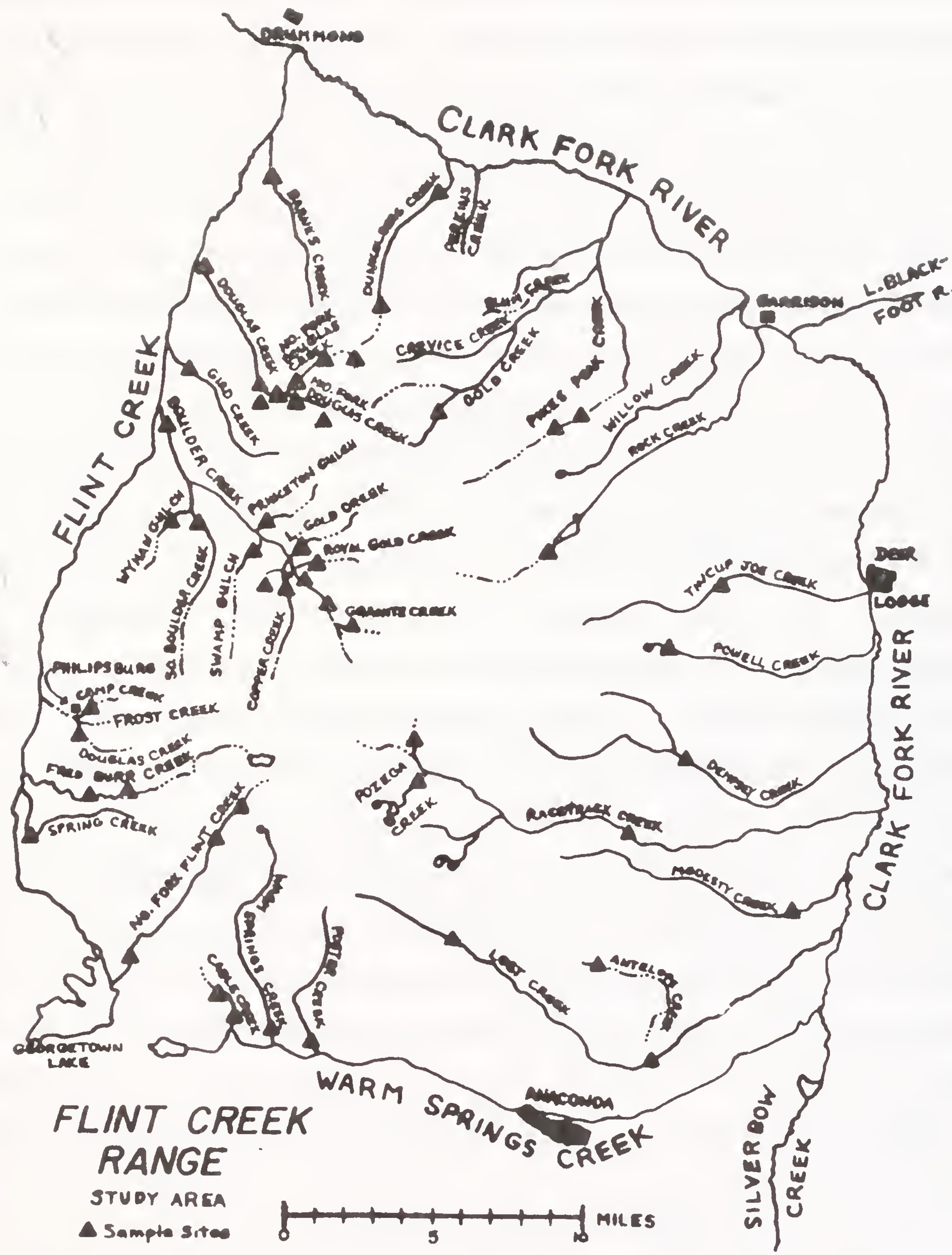

DRUMMOND
CLARK FORK RIVER
GARRISON
L. BLACK-FOOT R.
FLINT CREEK
DEER LODGE
CLARK FORK RIVER
PHILIPSBURG
GEORGETOWN LAKE
WARM SPRINGS CREEK
ANACONDA
SILVER BOW CREEK
FLINT CREEK
RANGE
STUDY AREA
Sample Sites
MILES
0
5
10

Figure 1

metamorphic rocks and pre-Cenozoic sedimentary rocks that have been intruded by several large bodies of granite. Two of the more important intrusions are the Philipsburg and Mount Royal batholiths. The actual origin of ore deposits in the range is very complicated and rather unclear but it is generally accepted that the period of ore deposition was between 40 and 50 million years ago. The span of time involved is believed to have been relatively brief. Important metallic deposits found within the range can be categorized as falling into five major groups: (1) Silver-base metal fissure fillings in granodiorite and replacement veins in sedimentary rocks; (2) Gold-base metal fissure fillings in granodiorite and replacement veins in sedimentary rocks; (3) Contact replacement deposits of copper-gold-magnetite or nearly pure magnetite; (4) Secondary manganese oxide deposits; and (5) Gold placers. These five categories account for the bulk of the total value of mineral production from the range which has been estimated at around $100 million. The Philipsburg District has produced the bulk of this value. Nonmetallic deposits found in the range are also commercially significant. The most important of these resources are the phosphate deposits of the Phosphoria Formation. It is believed that these sedimentary deposits resulted when increasing temperatures and pHs caused deposition of the high-grade material from phosphate-rich continental sea waters which once covered the area. The resulting beds since have been folded and faulted extensively. Greatest reserves of mineable material occur in the Maxville District, north of Philipsburg, where deposits range in thickness from one to four feet and contain 32 to 36 percent phosphorus pentoxide. Other nonmetallic deposits worthy of mention include limestone, silica, clay, sand and gravel and diatomaceous earth.

D) HISTORY OF MINING IN THE RANGE

The Flint Creek Range has had a rich and colorful history beginning with the first discovery of gold in Montana at Gold Creek in 1852. A book could be devoted to the details of historic mining development in the range, but that is not an objective of the report. However, included is a brief summary of mining activities within the various regions which may have lasting effects on water quality. Although the concept of mining "district" is outdated and provides no clear-cut boundaries, it is used here to describe general geographical locations (See Figure 2).

MINING DISTRICTS:

Douglas Creek District: Although not an important early-day hard rock district, significant quantities of phosphate rock were recovered from the Douglas Creek Mine beginning in 1964. Concentrate then was shipped to fertilizer plants in British Columbia. Production was relatively short-lived.

Maxville District: Located near the confluence of Flint and Boulder Creeks, this district has been a low producer compared to others. Some $100,000 worth of gold, silver and copper has been produced from veins occurring in folded and faulted sedimentary rocks.

South Boulder District: Encompassing a basin drained by Boulder Creek and its tributaries, the South Boulder or Princeton District primarily has been a gold producing area. Replacement veins and fissure fillings of numerous lode mines such as the Royal, Nonpareil, Powell, Gold Reef and Sunday have produced about $1,600,000.

Philipsburg District: The area around Philipsburg and Granite, though small, has been responsible for the majority of production in the entire range. From initial workings in 1865 to the present, the district has produced minerals worth in excess of $65,000,000 with silver accounting for about 90 percent of the total.

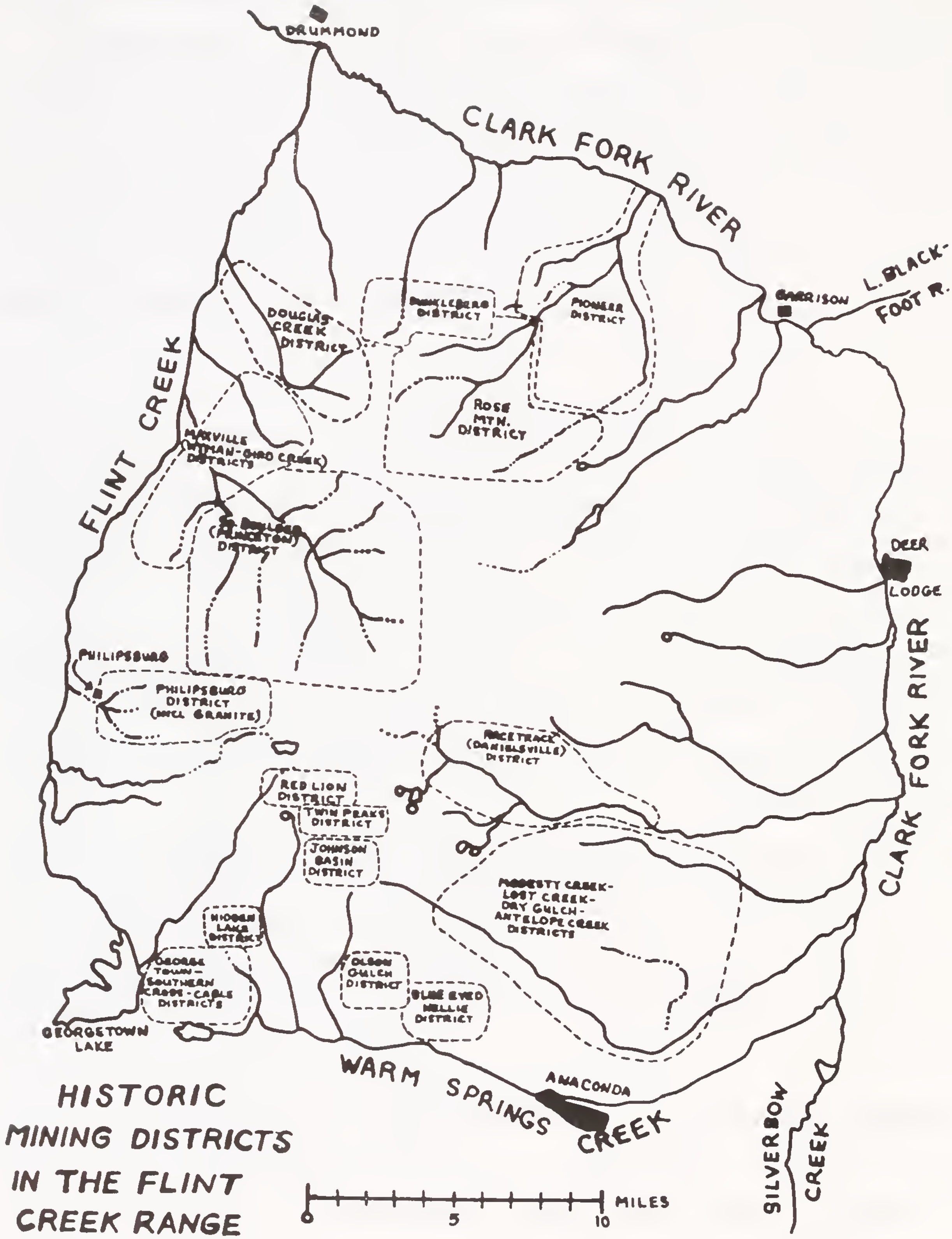

DRUMMOND
CLARK FORK RIVER
DUNKLEBERG DISTRICT
PIONEER DISTRICT
DOUGLAS CREEK DISTRICT
ROSE MTN. DISTRICT
GARRISON
L. BLACKFOOT R.
FLINT CREEK
MAXVILLE (WYMAN-BIRD CREEK) DISTRICTS
DEER LODGE
PHILIPSBURG
PHILIPSBURG DISTRICT (INCL GRANITE)
RACETRACK (DANIELSVILLE) DISTRICT
RED LION DISTRICT
TWIN PEAKS DISTRICT
JOHNSON BASIN DISTRICT
HIDDEN LAKE DISTRICT
MODESTY CREEK- LOST CREEK- DRY GULCH- ANTELOPE CREEK DISTRICTS
CLARK FORK RIVER
GEORGE TOWN- SOUTHERN CROSS-CABLE DISTRICTS
OLSON GULCH DISTRICT
BLUE EYED NELLIE DISTRICT
GEORGETOWN LAKE
WARM SPRINGS CREEK
ANACONDA
SILVER BOW CREEK
HISTORIC MINING DISTRICTS IN THE FLINT CREEK RANGE
0
5
10
MILES

Figure 2

Georgetown-Southern Cross-Cable Districts: This area between Warm Springs and the North Fork of Flint Creek is reported to be the most important gold mining area in Deer Lodge County and was active as late as 1951. Development of hard rock mining here began with the Cable Creek Lode Mine in 1866. By 1968, the districts had produced over $10,500,000, mostly in gold with silver second in importance.

Hidden Lake District: Located north of the Cable District, the Robinson and Hidden Lake Mines produced about $650,000, mostly in gold, from quartz and pyrite ores. Production continued into the 1940's.

Red Lion District: Mining in the Red Lion District, near the head of the North Fork of Flint Creek, began in the late 1880's. Although the area includes some 200 claims with a few worked as late as the 1960's, most of the total production of about $138,000 came from the Red Lion and Hannah Mines. Nearly half of this comparatively small total was reported before 1906.

Johnson Basin District: Activity in this district, which lies between Foster and Upper Warm Springs Creeks, falls into two distinct periods. Prior to 1906, prospectors worked replacement veins of high-grade silver ore. Then from 1954 to 1956, tungsten ore was the primary interest. District production approximates $240,000.

Olson Gulch District: Located east of Foster Creek, this district was primarily a silver producing area. Most activity had subsided by the 1890's but renewed interest in the 1960's added about 25 percent to a total production of some $83,600.

Blue Eyed Nellie District: Silver and lead produced from the Blue Eyed Nellie Mine yielded about $1,000,000 in 8 or 10 years after its discovery in 1880. No production has been reported from about 140 other lode claims in the district.

Modesty Creek-Lost Creek-Dry Gulch-Antelope Creek Districts: These relatively unimportant districts located along the southeast flanks of the range produced somewhere just over $50,000 worth of gold, silver, copper and lead. Activity in both lode and placer claims has been intermittent from the 1890's to the 1960's.

Racetrack (Danielsville) District: Despite construction of a mill and townsite near the head of Racetrack Creek, production from numerous claims in this district can only be considered token. The Dark Horse and Amazon Mines were active as late as the 1940's.

Pioneer District: This district includes the site of the first discovery of gold in Montana and contains those portions of Gold Creek and its tributaries which lie in Powell County. The area does not include any particularly important hard rock mines, but has been the site of extensive gold placer mining. Total production exceeded $1,300,000 by 1959.

Rose Mountain District: Headwaters and tributaries of Gold Creek in Granite County comprise this district. Occurrence of gold and copper in quartz veins, together with placer deposits, accounted for $50,000 production by 1959.

Dunkelberg District: Confined to an area about 2 by 5 miles in dimension in the northern end of the range, the Dunkelberg District was primarily a zinc, lead and silver producer. The important mines were the Forest Rose and the Wasa which accounted for the majority of $1,200,000 produced between 1880 and 1957.

III MINING PROBLEMS

Hard rock mining operations may affect water quality and the health of the biological components of streams in many ways. Problems most frequently encountered can be divided into three categories: 1) acid mine drainage, 2) heavy metal toxicity, and 3) sedimentation. Placer mining-related problems generally involve the third category. Additionally, destruction of aquatic organism habitat may occur through physical alteration of stream channels as a result of placer mining.

The first category, acid mine drainage, may result when previously unexposed material, in the form of mine tailings, comes in contact with oxygen and water. If metal sulfide compounds such as pyrite (FeS) are present, oxidation in the presence of water converts sulfide to sulfate and releases acid, ferrous ion and sulfate. Hydrolyzation of the ferrous ion yields ferric hydroxide or hydrous ferric oxide. This rusty-colored gelatinous precipitate, called "yellowboy", is oftentimes seen coating stream bottoms below oxidized mine tailings. The acid released by this series of chemical reactions is the major consideration from the standpoint of stream degradation. If sufficient concentrations of these acid solutions reach waterways, they may have direct effects on aquatic life or may act synergistically by increasing the toxicity of other chemical constituents in water. Acid mine drainage, by definition, characteristically has a pH of less than 6.0, sulfate and iron levels of greater than 75 and .5 mg/1, respectively, an alkalinity value of less than 20 mg/1 (as C_aCO_3) and a hardness of more than 150 mg/1 (Nichlos and Bulow, 1973).

One indirect method by which acid may affect streams is through the dissolution of metals. As the acid is formed in the tailings, it may dissolve metals occurring there and carry them to streams or groundwater via runoff, mine seeps or other surface waters. Dissolved metals may have toxic effects on aquatic organisms, make fish unsafe to eat and leave the affected water unsafe to drink. The degree of toxicity to freshwater organisms caused by heavy metals contamination of water is a function of many variables. One of the most important of these variables is the nature of the receiving water; specifically, the pH and hardness of the water. Solubility of heavy metals is a function of the acidity or alkalinity of the water in question. Additionally, solubility characteristics at different pHs may vary from metal to metal. Figure 3 demonstrates this relationship for several select metals species. The hardness of the receiving water is inversely proportional to the degree of toxicity afflicted by metals. Hard waters may cause precipitation of a large percentage of heavy metals contributed by mine drainage. These precipitates may or may not be toxic, depending on the particular metal species.

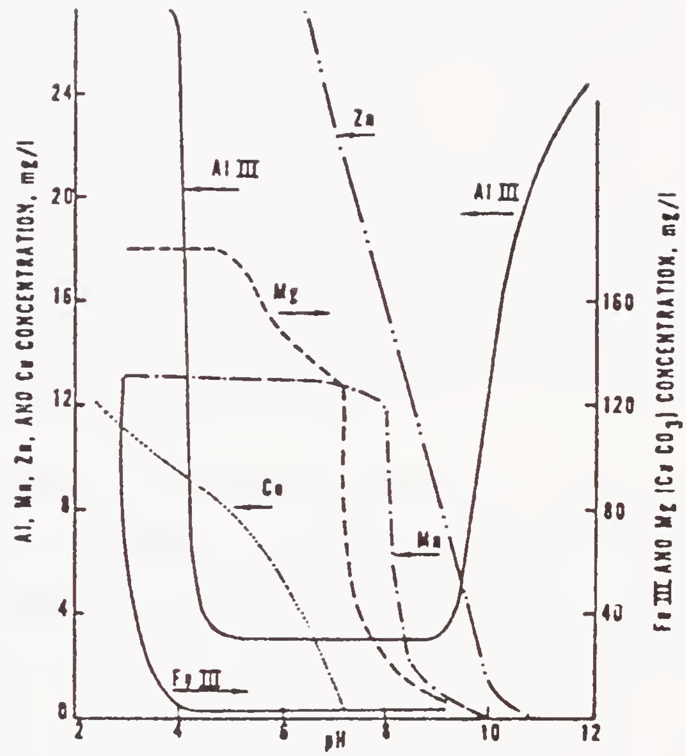


Fig. 3 —Solubility of Al, Mn, Fe III, and Mg in acid mine drainage at various pH's.

(Hill and Wilmoth, 1977)

An example of the relationship of hardness to heavy metal toxicity is given in Figure 4. Other important considerations affecting metals toxicity include the chemical state of the metal and synergistic or antagonistic effects which may result from combinations of metals in solution. Recommended maximum safe limits of select metals for drinking water, irrigation usage, and aquatic life are given in Table 1.

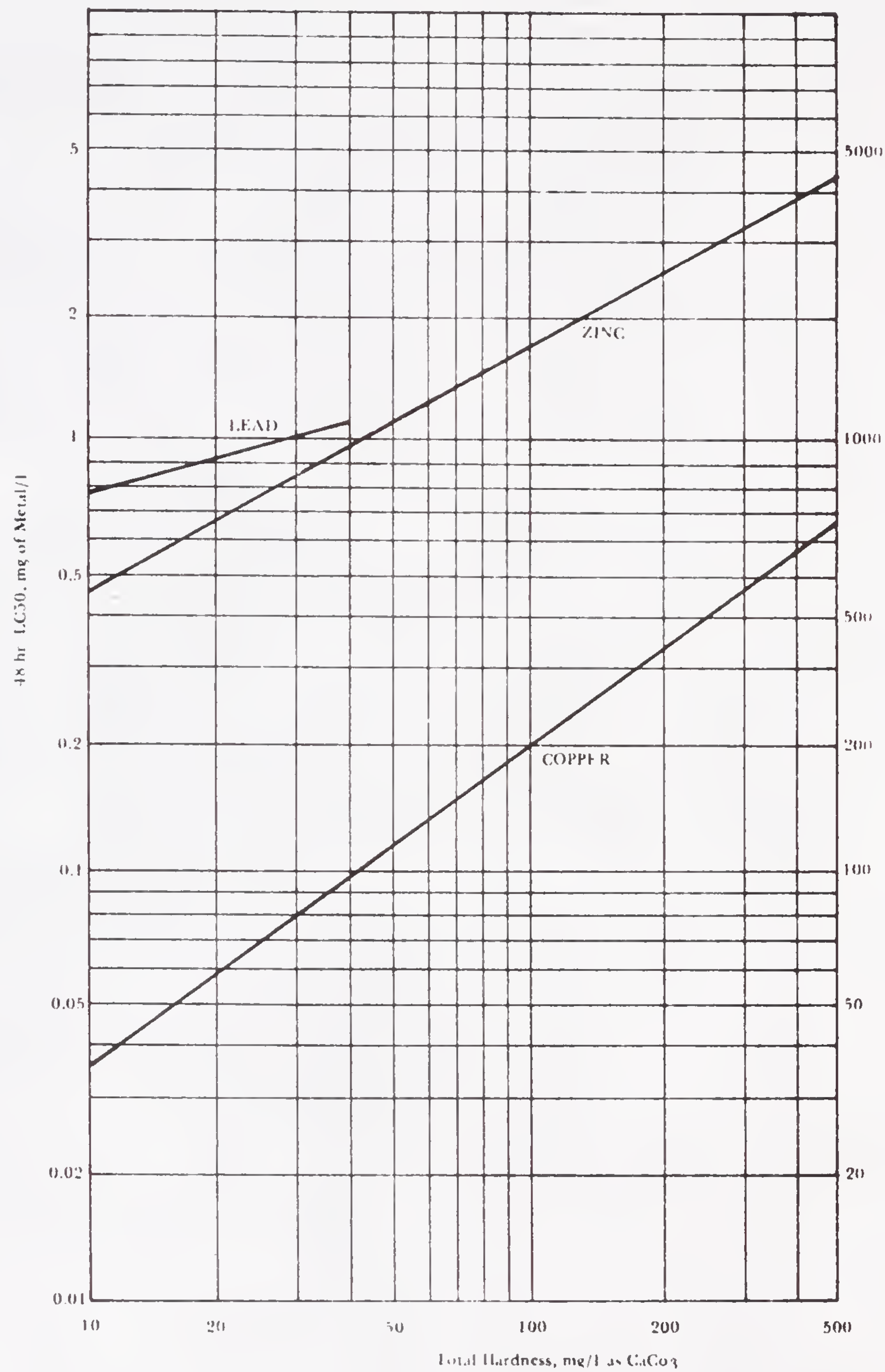
The addition of unnatural amounts of silt to waterways is another potential problem of mining operations. Destruction of protective ground-covering vegetation and exposure of tailings piles to runoff pose the threat of accelerated erosion and excessive sediment contributions to nearby streams. In severe cases, sediment may blanket stream bottoms thereby affecting aquatic invertebrate populations, fish spawning beds and dissolved oxygen levels. In less acute cases, suspended sediment may cause displacement of resident fish and reduce productivity of aquatic plants by decreasing light penetration.

IV METHODS

A) STATION AND PARAMETER SELECTION

Field surveys began in July 1978, just after snow melt, and were concluded in September when much of the range again became inaccessible due to heavy snowfall. Locations of mines, adits and tailings were acquired from historical data, existing maps and from information supplied by the U.S. Forest Service and Montana State agency personnel. Personal exploration of the area revealed additional mine sites. Due to the expanse of the study area, it was virtually impossible to examine each of the hundreds of existing claims and defunct mining properties. Therefore, the degree of effort expended at each drainage was based on the intensity of past and present mining activity or the likelihood for future activity within that basin. Nearly all of the permanent streams and their tributaries within the

Figure 4 *The 48-Hour Lethal Concentrations of Three Heavy Metals for Rainbow Trout* (Salmo gairdneri). *(Similar Relationships Exist for Other Species of Fish.)*



(U. S. Environmental Protection Agency, 1972)

Table 1. RECOMMENDED LIMITS FOR CERTAIN TOXIC ELEMENTS

Element	Detrimental Effect on Aquatic Life* (conc. in mg/1)	Recommended Limits for Drinking Water* (conc. in mg/1)	Recommended Limits for Long-Term Irrigation** (conc. in mg/1)
Arsenic	1.1	.05	.10
Cadmium	.0005	.01	.01
Copper	.025	1.0	.20
Iron	.2	.3	5.0
Lead	.1	.05	5.0
Manganese	1.0	.05	.20
Mercury	.008	.002	---
Silver	.003	.05	.05
Zinc	.01	5.0	2.0

* Pedersen, R., 1977.

** U. S. Environmental Protection Agency, 1972.

range were at least briefly examined.

Parameter measurements selected for this study can be divided into three categories: 1) chemical, 2) physical and 3) biological. Chemical determinations performed on water samples included sulfate, pH, total phosphorus and the following metals in total recoverable form: arsenic, cadmium, copper, iron, lead, manganese, mercury, silver and zinc. Sulfate and pH were used to assess the degree of influence by acid mine drainage. Sulfate, as previously discussed, is a by-product in the series of reactions which produce acid mine drainage and it frequently occurs in substantial concentrations in such drainage. However, it may also be found in high concentrations in surface and groundwaters due to natural occurrence in soil and rock. Irrigation return flows may also contribute significant quantities of sulfate in certain soil types. Therefore additional parameters, such as pH, must be used in conjunction with sulfate levels to determine if problems exist. Total phosphorus concentrations were measured to determine influences of the Phosphoria Formation on water quality. Concentration of heavy metals in streams was shown by total recoverable metals. The total recoverable form indicates all readily detectable quantities occurring in the dissolved state and in suspended sediments. In clear samples with little or no suspended material, the concentration of total recoverable metals will very closely approximate the dissolved quantity. Additional metals data found in the appendices of this report includes dissolved, total recoverable and total forms of metals. The latter of these three types of analyses, the total form, differs from the total recoverable form in that a digestion is performed on the sample and suspended sediments. This effectively makes all extractable metals available for detection and the result will be as high or higher than the concentration determined by either of the other two methods. The total recoverable metals concentration, as measured on samples collected for this study, is probably of greater biological significance than the other two forms. It

represents dissolved concentrations which are most easily absorbed by aquatic plants and animals, as well as readily available forms of metals found in the sediments, which may be absorbed by organisms through direct contact with the sediments.

Physical parameters utilized were streamflow, specific conductance, total suspended solids and water temperature. Flow rates are necessary data for determining loads of metals, acids and other chemical constituents in streams while specific conductance was used as an indirect measurement of dissolved solids. Total suspended solids levels quantified sediment loads. Stream water temperature, though seasonally and diurnally variable, is an important biological consideration. Characterization of the biological health of streams at the time of examination was accomplished through collection of qualitative periphyton samples from natural substrates and field examination of abundance and diversity of aquatic invertebrates. Periphyton is the community of algae that live on and attach to the stream bottom. In streams of the Flint Creek Range it is probably the most important community of primary producers. Members of the periphyton community are valuable pollution indicators and subtle shifts among these algae can signal environmental disturbances.

Diatoms are important members of periphyton communities in mountain streams. *Achnanthes* and *Nitzschia* are two particularly useful diatom indicators. *Achnanthes* almost always is found in significant numbers, but only in water having a high concentration of dissolved oxygen, approaching saturation. *Nitzschia*, on the other hand, is usually associated with waters high in nitrogen. The relative abundance of *Nitzschia* is often directly proportional to the amount of nitrogen contained in the water.

Clean waters usually have many different species -- with some fairly common but with none really dominant. Polluted waters have fewer species -- often with one or two species very abundant. Diversity can be measured simply by counting the number of

species in a sample or by calculating a diversity index. The most widely accepted diversity index is the Shannon-Weaver Index or $\bar{d}$. Bahls (1979) found that benthic diatom associations in unpolluted Montana streams average more than 25 species with $\bar{d}$ values greater than 3. Species numbers significantly below 25 and diversity values significantly below 3 are indicators of pollution.

Aquatic invertebrates, like the periphyton, are differentially tolerant to pollution. However, they have considerably longer life cycles than those of periphyton organisms; up to three years as compared to just a day or two for many algae. Consequently, they reflect water quality over a much longer period of time.

B) FIELD METHODS

1) Field Observations

Mine sites were inspected for adits, open pits and tailings piles. Obvious problems such as acid mine drainage and potential or actual sources of erosion and sedimentation were noted. These and areas without evident problems were surveyed by the following methods.

2) Water Sampling

Unfiltered grab samples were collected from streams, seeps and mine discharges in three, one-liter plastic bottles per site. Samples to be analyzed for heavy metals and total phosphorus were preserved with 5 ml. concentrated nitric acid and 4 ml. mercuric chloride solution, respectively, per one liter of sample. The third sample to be analyzed for sulfate, pH and the physical parameters was collected unpreserved. All samples were transported on ice to the laboratory.

3) Flow Measurements

Flow rates of streams were measured at the time of sample collection using either a Pygmy or Price type AA current meter where water depths and velocities were

not prohibitive. Velocity measurements and depths of at least ten subsections were taken at a uniform stream cross-section and summed to determine total discharge in cubic feet per second (cfs). Seeps and mine discharges were usually measured with a bucket and stopwatch, calculated as gallons per minute discharge (gpm) and converted to cfs units.

4) Biological Survey

Periphytic algae were collected from natural substrates on the stream bottom. Quantities of larger, macroscopic species were picked in proportion to their abundance relative to one another and to the attached diatom (slime) community as a whole. Accordingly, an appropriate amount of the diatom community was collected by scraping rocks and other submerged substrates with a razor blade, pocket knife or scalpel. Different substrates in turn were scraped in proportion to their areal coverage. An effort also was made to collect algae from both pools and riffles, again in proportion to the extent these stream features prevailed at a given site. The ultimate objective is to obtain a sample of algae that is a miniature replicate of the stream's periphyton community. Samples were preserved with Lugol's (IKI) solution and returned to the lab for analyses.

Examination of the abundance and diversity of aquatic invertebrates at each sample site was limited to a routine field observation. An experienced aquatic biologist can tell by such observation whether water quality is significantly degraded. Minor stress to the invertebrate community, however, is not always detectable by this cursory method.

C) LABORATORY METHODS

1) Chemistry

Water samples were analyzed by the Chemistry Laboratory Bureau of the Department of Health and Environmental Sciences. Analytical procedures were in accordance with United States Environmental Protection Agency (1974) or American Public Health

Association (1971, 1975) recommendations. Methodology is summarized below:

Parameter	Method
pH	pH Meter
Specific Conductance	Wheatstone Bridge
Sulfate	Manual Turbidimetric or Automated Methylthymol Blue
Total Phosphorus	Persulfate Digestion, Automated Ascorbic Acid Reduction
Total Suspended Solids	Filtration, Evaporation at 105°C, Gravimetric
Total Recoverable Metals (As, Cd, Cu, Fe, Pb, Mn, Hg, Ag, Zn)	Atomic Absorption

2) Biology

Periphyton samples were analyzed at the Water Quality Bureau, Department of Health and Environmental Sciences. Conspicuous nondiatom algae were removed from the samples, examined microscopically and identified to genus. The relative abundance and rank of each significant nondiatom genus and the diatom community as a whole were then recorded. A portion of the diatom community was used to prepare a permanent, randomly strewn mount using sulfuric acid and potassium dichromate as the oxidizing agents and Cargille's "Carmount-165" as the mounting medium (A.P.H.A., 1975). A diatom species proportional count was performed on each slide following the technique outlined by Weber (1973), except that in excess of 300 rather than 250 cells were tallied. The results were used to compute percent relative abundance (PRA) of indicator taxa and diatom species diversity ($\bar{d}$) using the Shannon-Weaver formula recommended by Weber (1973):

$$\bar{d} = \frac{C}{N}(N \log_{10} N - \Sigma n_i \log_{10} n_i)$$

where C = 3.321928; N = total number of individuals; and n_i = number of individuals in the i^{th} species.

V RESULTS AND INTERPRETATIONS

A summary of chemical and physical data collected for 51 sample stations in the Flint Creek Range as part of this study are presented in Table 2. Additional existing chemical and physical data are included. Diatom community structure data are given in Table 3. Additional periphyton data can be found in Appendices 1 and 2. Results and interpretations of the collective findings for each station follow. Field observations of areas of past or present mining activity that were not sampled are included. Sampling station locations are identified in Figure 1.

A. Flint Creek Drainage

1. Barnes Creek near mouth - Although the upper reaches of the creek were not surveyed, the authors feel that degradation of this stream resulted primarily from poor agricultural practices rather than mining. Total suspended solids and total phosphorus values were unusually high (842 mg/1 and .15 mn/1, respectively) and the majority of the streambed was covered with sediment. Metals concentrations were generally low with the exception of iron which was sufficiently high to impact some fresh water aquatic organisms. Sulfate was unexplainably high compared to the other stations (124.0 mg/1) and perhaps originated from local geologic conditions and irrigation return flows. The specific conductance value (676.0 umhos) was the highest of all stations indicating substantial dissolved solids. Periphyton and aquatic invertebrates were abundant where rocks could be found in the streambed. Diatom diversity was high in these areas (3.80) but a low percent relative abundance (PRA) of *Achnanthes*, which is a genus requiring a firm substrate, confirms the observation of silt deposits.

2. Douglas Creek at mouth - Douglas Creek at its confluence with Flint Creek exhibited no apparent mining-related stress. Aquatic insects were abundant, periphyton was common and diatom diversity was the highest calculated of all sites (5.12). The total phosphorus concentration was relatively high (.06 mg/1) and

it may be associated with agricultural contributions or past phosphate mining activity upstream. It might also be a normal background level caused by influence of the Phosphoria Formation through which the drainage flows. The actual sources were not determined.

3. Douglas Creek below seep from adit - Water quality at this site located just above the abandoned Cominco Company phosphate mining operations was very similar to the site at the mouth with the exception of zinc, silver and total phosphorus levels. Zinc and silver concentrations fell just within range of levels capable of adversely affecting aquatic life (.015 mg/1 and .005 mg/1, respectively). Total phosphorus levels were half that found at the downstream site (.03mg/1). Aquatic insects were abundant, as was periphyton. Diatom species diversity was lower (3.35) than at the mouth, but still within the range of an unstressed stream.

4. Seep from adit to upper Douglas Creek - This seep originated at an abandoned mine adit and was contributing an appreciable quantity of flow to Douglas Creek (14 percent of total flow). Chemically, physically and biologically the seep resembled a spring creek. Aquatic plants, including periphyton and insects, were abundant, the water clear and cold. Metals levels were insignificant. Despite the lush algae association, diatom diversity was somewhat low (2.20). *Diatoma hiemale* ranked third as the dominant diatom taxon. *D. hiemale* is a stenothermal species, that is, it usually occurs over a temperature range of 0 to 5^{o}C (Lowe, 1974). It is thus speculated that the lower diversity resulted from thermal rather than chemical stress.

5. Douglas Creek below confluence North and Middle Forks - This site is located a short distance above the seep and was appreciably different from the site below the discharge in zinc concentration only. The level here was slightly higher (.018 mg/1) and was likewise capable of having adverse affects on aquatic life.

Aquatic invertebrate and periphyton community observations, however, indicate no substantial stress to the biological community.

6. North Fork Douglas Creek at mouth - The North Fork was contributing less than 10 percent of the total flow to Douglas Creek at the time of examination. Conditions at this station began to suggest mining impact. Zinc levels were ten times greater than concentrations known to affect aquatic life (.110 mg/1). Cadmium levels were four times higher (.002 mg/1) and sulfate had increased three-fold (20.5 mg/1) over Douglas Creek below this site. Although aquatic invertebrates appeared plentiful, diatom community structure indicated slight stress. Major taxa indicated cool, well oxygenated water subject to a moderate amount of nitrogenous enrichment. The slight stress here appears to be due to a combination of elevated metals and eutrophication. The cause of the latter is unknown but may be due to contributions from livestock.

7. North Fork Douglas Creek .5 mile below Wasa Mine - About 2.5 miles upstream, water quality was significantly worse. Cadmium levels had doubled (.004 mg/1) and zinc concentrations were twelve times higher (1.3 mg/1) or 130 times over levels toxic to aquatic life. Sulfate levels (123.0 mg/1) were six times that of the previous station. Periphyton data indicated severe stress and aquatic invertebrates were entirely absent. The stream bottom was covered with "yellow boy", suggesting acid mine drainage influences.

8. North Fork Douglas Creek just below Wasa Mine - Cadmium, copper, iron and zinc levels at this station were all sufficient to have toxic affects on aquatic life and were among the highest observed during this study. The creek actually begins at the Wasa Mine site and the exposed ore and tailings through which it flows are undoubtedly responsible for the metals contributions. Additionally, it is suspected that this exposed material is a critical sediment source during runoff. "Yellow boy" created a thick deposit on the creek bed throughout the area. The Wasa Mine is situated on a deposit of zinc ore and as early as 1916, it was likely

causing degradation of water quality. J. T. Pardee (1917) wrote "where the lode (Wasa) is cut by Douglas Creek it is oxidized and much of its zinc is leached out." This station had a very simple flora consisting almost exclusively of the green alga Stigeoclonium, which was dominant, and the diatom Achnanthes minutissima. Patrick et al. (1975) reported Stigeoclonium lubricum to be unaffected by levels of trace metals that were toxic to other algae. Bahls (in Pedersen, 1977) reported that Achnanthes minutissima was the only significant diatom species in several streams of the northern Boulder Batholith which were severely impacted by mining wastes. Overall diatom diversity was the lowest observed at all stations (.11). Invertebrates were absent.

9. Middle Fork Douglas Creek at mouth - The Middle Fork contributed over 90 percent of the flow of Douglas Creek when it was observed. This is extremely fortunate because its high quality almost completely offsets metals contributions from the North Fork through dilution. The only detectable metal was arsenic (.001 mg/1) and it occurred at concentrations a thousand times less than might affect aquatic life. Other chemical and physical parameters indicated high quality water. The flora here consisted of moss, Phormidium and a diatom association dominated by Achnanthes minutissima and Navicula minima. The relative abundance of N. minima correlated significantly with ammonia and phosphate concentrations in the East Gallatin River (Bahls, 1973). However, total phosphorus at the mouth of the Middle Fork of Douglas Creek was not unusually high (0.023 mg/1) and metals were all at or below detection limits. Thus the source of apparent moderate biological stress at this site remains unknown. Aquatic invertebrates were abundant.

10. Seep from adit above Middle Fork Douglas Creek - Some 2.5 miles upstream from the mouth on the Middle Fork another mine seep was observed. It too contributed a substantial quantity of flow to the creek (20 percent). Chemical testing revealed

high quality water with no indication of mine-caused pollution. Total phosphorus concentrations were relatively high (.05 mg/1) and are probably related to the local geology of the Phosphoria Formation. All heavy metals examined were below detectable levels. The seep supported luxuriant growths of moss and diatoms, but no nondiatom algae. The diatom flora was dominated by Diatoma hiemale and only secondarily by Achnanthes minutissima. As previously mentioned D. hiemale is a stenothermal diatom occupying a narrow temperature range. The rather low diatom species diversity of 1.88 is probably, like the seep on main Douglas Creek, related to thermal, rather than chemical, stress.

11. Gird Creek near mouth - At the time of examination, Gird Creek was flowing a mere 1 cubic foot per second, most of which was being contributed by a tributary flowing from the north. Several abandoned lode mines exist in the upper reaches of the main drainage but were inaccessible due to a washed out road. Results of chemical analyses give no indication of mining-related problems. Logging activity in the drainage may contribute to sedimentation at times of the year and significant irrigation usage of the creek may be partially responsible for the relatively high total phosphorus value of .05 mg/1. Periphyton analysis indicated an unstressed moderately enriched (nitrogen) environment. The nitrogen as well may originate from agricultural influences.

12. Boulder Creek near mouth - Boulder Creek is one of the largest streams directly draining the Flint Creek Range. It is a receiving stream for at least nine tributary creeks, the entire drainage encompassing perhaps 100 square miles. Boulder Creek receives its name from the many large granite boulders that comprise the valley floor and streambed. Water quality determinations of the creek just above its confluence with Flint Creek indicated very high quality with the exception of zinc levels which just fell at the concentration capable of affecting aquatic life (.01 mg/1). Aquatic insects were nonetheless extremely abundant and diverse,

perhaps due to the hardness of the water buffering any toxic effects. The periphyton community, as well, indicated cool, well oxygenated, unpolluted waters. Diatom diversity was relatively high at 3.42. Trout were present.

13. South Boulder Creek near mouth - A north-flowing tributary of Boulder Creek, South Boulder Creek, exhibited excellent water quality. Dissolved solids (as determined from specific conductance) were very low and all the metals tested were below detection limits except iron and manganese. Only iron exceeded recommended limits but apparently it posed no threat to aquatic life because invertebrates were abundant and periphyton community structure indicated an unstressed, clean water environment.

14. Wyman Creek above confluence with South Boulder Creek - Wyman Creek is a tributary to South Boulder and about half as large. The creek flows parallel to the main South Boulder drainage for most of its length, the two being divided by a ridge some two miles wide. It is interesting that the chemical, physical and biological character of Wyman Creek differed so greatly from South Boulder Creek while the two drained similar terrain. Dissolved solids levels were relatively high for a mountain headwater stream and total phosphorus was twice as high as South Boulder Creek. Metals levels were all below concentrations which may affect aquatic life. Aquatic invertebrates were plentiful and diatom diversity was high (3.72). Percent relative abundances of *Achnanthes* and *Nitzschia* species were both low and roughly equal (8.5 and 7.3, respectively) unlike South Boulder Creek where *Achnanthes* species greatly outnumbered *Nitzschia*. This may signify slight amounts of nitrogen enrichment in Wyman Creek although these results cannot be considered conclusive. An old mill site and several prospects were surveyed several miles up the drainage but no evident problems were observed.

15. Princeton Creek near mouth - Princeton Creek is a southwestward-flowing tributary of Boulder Creek joining it about four and one-half miles southeast of

Maxville. Water quality in Princeton Gulch at the time of the survey was very similar to that observed in Boulder Creek near the mouth except that no zinc was detectable. The creek was very small, amounting to no more than a trickle (.5 cfs). Aquatic invertebrates were common and periphyton examination indicated high quality, well-oxygenated water. Placer operations have been intermittently active on the creek since 1913 (Lyden, 1948) and tailings piles are evident from the mouth upstream for some distance. It is felt that these may be critical sources of sediment contributions to both Princeton and Boulder Creeks during runoff. Much of the material is extremely coarse, including very large granite boulders and revegetation will be slow. Several lode mines were surveyed in the drainage (Moonlight Mine, Thursday-Friday Mine) and at least one groundwater seep observed near old workings, but field measurements and observations indicated no present impact to the creek.

16. Swamp Creek near mouth - Another Boulder Creek tributary, Swamp Creek at the site of observation was a steep gradient, extremely swift and cascading stream. Dissolved solids levels were the lowest of all the streams surveyed (around 17 mg/1). This probably was due to the granitic nature of the terrain and poor soil development. Total phosphorus levels were about average for the Boulder Creek drainage. Heavy metals all fell below detectable levels except for iron, which was unexplainably high for a stream of this nature. The source was not located. Invertebrates did not appear to be overly abundant, perhaps because the stream bottom was primarily decomposed granite (coarse sand). This is not an ideal habitat for aquatic invertebrates. Periphyton examination indicated no stress.

17. Copper Creek above mouth - The largest Boulder Creek tributary and flowing parallel to Swamp Creek, Copper Creek was also of very high quality. Iron and manganese were the only detectable metals and they occurred at fairly low concentrations. Dissolved solids were again very low (around 25 mg/1) as was total phosphorus (.01 mg/1). Copper Creek had a flora typical of a cold, high mountain

stream. Diatom examination revealed a relatively high diversity but low overall abundance suggesting some possible stress. With no evidence of metals pollution, it is likely that this is merely due to the natural austerity of the aquatic environment. Aquatic invertebrates were abundant as were trout.

18. Royal Gold Creek above mouth - Zinc and cadmium levels observed here fell within ranges capable of affecting aquatic life. Other chemical and physical parameters, however, indicated high quality water. Periphyton analysis showed cold, highly oxygenated water and no apparent stress. Invertebrates were not overly common but this may have been due to the natural sterility of the environment rather than man-caused stress. Mines at the head of the drainage near Altoona Lakes were inspected for problems and several mine seeps were observed. Field observations and measurements, however, showed them to be groundwater of apparently high quality with no evidence of acid, metals or sediment problems.

19. Little Gold Creek above mouth - This is another of the larger Boulder Creek tributaries. Existing water quality at the time of examination was excellent. No parameters, including periphyton community structure and field observations of aquatic invertebrates suggested any type of man-caused or other stress. Logging activity in the drainage was not surveyed for erosion and sedimentation threats to the creek.

20. Seep from old tailings pond to Boulder Creek - This was located adjacent to Boulder Creek near the former location of the Nonpareil Mine and just above the mouth of Royal Gold Creek. The source of the water was a spring originating above the old pond and near the creek. From this point the spring flowed across the bottom of the dry pond, where it had cut a channel and through an earth dam at the lower end of the pond. Although acid mine drainage by definition (see page 13) was not detectable here, "yellow boy" was visible on the channel bottom in the vicinity of the tails pond, suggesting a past or intermittent acid mine drainage situation. The low volume flow (.3 cfs) eventually reached the main creek some 100 yards below this point after first entering a beaver pond.

Although the pH value was not unusually low, nor sulfates high, metals levels measured at the outfall of the tailings pond were significant - cadmium, copper, iron, lead and zinc with values of .001, .04, 2.1 and .430 mg/1, respectively, all exceeded concentrations capable of having adverse affects on some form of aquatic life. Arsenic levels were the highest observed at all stations but not sufficient to cause toxicity. Impact to Boulder Creek itself was probably very minimal during the time of observation due to an immediate dilution of at least 100 to 1. This would effectively reduce all metals concentrations to safe levels, given the present high quality of Boulder Creek itself. However, if the small flow was capable of dissolving these quantities of metals, it seems likely that a substantial quantity of run off could contribute a major metals load to Boulder Creek. It if felt that spring snowmelt or heavy rains may fill the pond to at least a few inches depth. No periphyton sample was taken from the pond outfall, but a marginal number of aquatic invertebrates were observed.

21. Boulder Creek below Brooklyn Mine - This station on upper Boulder Creek was located about 1 mile below the Brooklyn Mine (inactive) and at the site of a very poor logging operation along the creek bottom. The stream was choked with slash and a buffer strip had not been maintained to protect streambank stability. The Brooklyn appeared to have been a sizeable operation as evidenced by large tailings piles, shafts, open pits and abandoned buildings. No actual discharges to surface waters were observed in the vicinity of the mine. However, an open pit filled with bluish-green water was found on the northeast slope above the creek and overflow from it trickled down a steep incline through old tailings. The discharge seeped back into the ground at the bottom of the slope. Again, runoff may create a much different situation. Samples of the water were not taken but field specific conductance measurements indicated a dissolved solids level of about 315 mg/1. Mine tailings were observed along the stream course in the canyon below the Brooklin Mine. Samples taken at the station below the mine showed no major impact to Boulder Creek. No metals

problem existed and pHs and sulfates were normal. Periphyton analysis revealed a dominance of Achnanthes species over Nitzschia and a healthy diversity. Invertebrates were plentiful and trout were observed. Poor logging practices along the stream probably posed a greater threat to water quality and aquatic life than the abandoned mine.

22. Boulder Creek above Brooklyn Mine - The only significant differences between water quality at this site and below the mine were in iron and arsenic concentrations. An increase from .03 to .13 mg/1 was noted for iron and from .001 to .002 mg/1 for arsenic, from above the mine to below, but even the higher levels were not capable of causing impacts to aquatic life. A very slight increase in zinc was also noted below the mine site, but it was not statistically significant due to analytical precision. Periphyton analysis indicated, like the lower station, a favorable environment and an unstressed community. Aquatic invertebrates were abundant and diverse. Recent activity by the Black and White Mining Company was noted in this general area but no current problems were seen.

23. Granite Creek near mouth - This small swift tributary to the headwaters of Boulder Creek drains the Finley Basin area, a scenic alpine region near the heart of the Flint Creek Range and the site of active mineral exploration by Union Carbide Corporation (J. Burke - personal communication). Chemical analysis of the water revealed significant quantities of zinc (.013 mg/1) capable of detrimentally affecting aquatic organisms. Other parameters were well within "safe" levels. Granite Creek at this station had a flora typical of a cold, high mountain stream. Diatom diversity was lowered because of the abundance of Diatoma hiemale (58.3 PRA), an indicator of consistently cold water. The questionable stress at this site may have been due in part to the zinc levels, but it was more likely a result of low water temperature. Aquatic invertebrates appeared abundant. A survey of the upper reaches of Granite Creek revealed no evident mining-related water quality

problems. Effects of fairly extensive road building activities related to current mineral exploration in Finley Basin were not assessed but may pose future sedimentation threats to surface waters.

24. Camp Creek above Philipsburg - This very small brook was running cold and clear when examined. Despite its appearance, Camp Creek was carrying a considerable load of zinc (.05 mg/1). Sulfate levels were the highest observed (206.0 mg/1) and specific conductance the second highest observed (654.9 umhos) of all stations sampled. It is felt that this has resulted from extensive prospecting in the drainage. Surprisingly, the pH value was very high (8.66) indicating slightly alkaline rather than acidic waters. The aquatic flora consisted of *Vaucheria*, moss and a diatom association dominated by *Achnanthes* species (52.4 PRA) and *Navicula minima* (31.5 PRA). Diatom diversity was somewhat low at 2.50 indicating stress. The zinc levels which were present may have been the responsible agent or it might have been the result of more severe pollution at an earlier date (during runoff) or on intermittent occasions. Camp Creek apparently never reaches other surface waters but goes underground.

25. Douglas Creek below tailings at Philipsburg - Another small stream draining the area above Philipsburg, Douglas Creek, like Camp Creek, was impacted by past mining activity but to a much greater degree. Old mine tailings and at least one washed-out tailings pond contributed large quantities of zinc and manganese to the creek. Sulfate, arsenic, cadmium, copper and lead concentrations were significant. Douglas Creek at this station had a simple aquatic flora consisting of an abundance of the green alga *Mougeotia* and a sparse diatom association dominated by *Achnanthes minutissima* (40.3 PRA). Palmer (1977) lists *Mougeotia* as an indicator of high acidity. Although the pH at this site (6.95) was not very acidic, it was nevertheless the only pH below neutrality (pH = 7) of all the water samples tested. Perhaps not coincidentally, this was also the only station where *Mougeotia* was present in

abundance. Since levels of cadmium, copper, iron, manganese and zinc all exceeded concentrations known to affect freshwater aquatic life, there is little doubt that elevated metals accounted for the biological stress at this site. Aquatic invertebrates were entirely absent from the stream. Other data (See Table 2, WQB, June, 1977) collected during runoff showed much higher metals levels and nearly ten times more suspended solids (silt) than were observed on this occasion. Past sedimentation problems were obvious from the blanket of silt on the creek bed. Biological stress is therefore assumed to be much greater during spring time and heavy rainfall. It is not known whether Douglas Creek reaches other streams (Flint Creek) and causes impacts. It may, like Camp Creek, dry up or go underground.

Granite area field observations - The old Granite town and mine site were searched for water quality problems on foot or by four-wheel drive where roads and jeep trails existed. Surrounding areas of past mining and prospecting activity were surveyed to a limited degree in the same manner. Activity has been so extensive in the adjacent hills that it was impossible with available time, to do a thorough job. Fortunately, the area is quite dry and despite numerous mine dumps, degradation of surface waters was not observed. Numerous mine seeps and springs were located but field determinations of pH and specific conductance showed them to be high quality groundwater not warranting further testing. Frost Creek, which was flowing in its headwaters, was dry at Philipsburg and was not sampled.

26. Fred Burr Creek below Rumsey - Fred Burr is a tributary to Flint Creek and is located south of Philipsburg. A lake above the headwaters of the creek supplies domestic water to the town of Philipsburg. The old town of Rumsey and one of the larger mills of the Philipsburg area once stood along Fred Burr creek at a point about one mile above this sample station. The mill employed a pan amalgamation method utilizing large quantities of mercury to isolate silver from the ore. Processed ore was evident along the creek at this site and near the ruins of the mill.

Chemical analysis of samples collected here showed arsenic and manganese to be well above background levels for streams of the Flint Creek Range but neither were above known lethal levels for freshwater aquatic life. The periphyton community had a fairly healthy nondiatom flora consisting mainly of Nostoc, Spirogyra, Phormidium and Chaetophora. However, the diatom flora was almost totally dominated by Achnanthes minutissima (91.4 PRA), indicating a severely stressed environment unsuitable for many of the less tolerant diatom taxa. Aquatic invertebrates were fairly abundant. A study of metals concentrations in fish tissue of the upper Clark Fork River identified elevated levels of total mercury and total lead in rainbow trout and significant levels of total mercury in the water of Fred Burr Creek (Van Meter, 1974). Total recoverable mercury was not detectable at this location when sampled for this study, but runoff conditions may present different conditions. Van Meter's report failed to mention the season at which water samples were taken. Additionally, mercury apparently complexes readily with other compounds possibly allowing precipitation or making detection difficult (personal communication, William Kerr, Chemist). The diatom community may be inhibited for reasons such as this.

27. Fred Burr Creek above Rumsey - Metals levels above the Rumsey town and mill site were consistently lower (most not detectable) than below with the exception of mercury which was surprisingly higher. This is probably due to the previously mentioned difficulty in detection. Concentrations of mercury here were still well below toxic levels. Other parameters suggested clean water. The aquatic flora was dominated by diatoms; moss and three genera of green algae were of secondary importance. Although Achnanthes minutissima again dominated the diatom association (61.8 PRA), certain "pristine water" species (Hannaea arcus, Didymosphenia geminata and Gomphonema olivaceoides) were also present. Thus the slight stress detected here probably was natural in origin rather than mining related. Invertebrates were noticeably abundant (more so than the downstream station). A small mine adit seep

was observed at Rumsey. The seep flowed for about 50 feet after leaving the shaft and then went underground. Samples were not taken, but the discharge appeared very similar to seeps in the Granite area which were apparently clean groundwater. No evidence of acid mine drainage was seen.

28. Spring Creek (Summer Gulch) near mouth - Water quality at this site near highway 10A could best be described as clean but moderately enriched. All metals were below toxic levels, total phosphorus was relatively high (.05 mg/l) and diatom community structure suggested some degree of nitrogenous enrichment. Diatom diversity was high and aquatic invertebrates were characteristic of clean, cold, highly oxygenated waters. Brook trout were observed.

29. North Fork Flint Creek near mouth - Flint Creek proper originates at the outfall of Georgetown Lake, below a Montana Power Company hydroelectric dam. The North Fork of Flint Creek, a southwesterly flowing stream of some nine miles in length, is the only major surface inlet to the lake. Although mining and prospecting activity have been significant in and adjacent to the North Fork drainage (Red Lion District and others), water quality was excellent at the time it was surveyed. Metals, dissolved solids and sulfate were all very low. Total phosphorus levels here were well below what seemed to be normal background concentrations for streams draining the west side of the Flint Creek Range. This was most likely a result of the location of the Phosphoria Formation. Tributaries in the western and northern portions of the range apparently contact more of the belt than do southern streams. Biological analysis indicated a healthy and diverse diatom community and an abundance of aquatic invertebrates.

30. North Fork Flint Creek below Golden Jubilee Mine - This station was located about one mile below an active mining operation adjacent to the creek. Activity in the past had been open-pit mining but at the time of observation, ore was being extracted by drilling into the mountain side and blasting it loose. Samples were

collected at this site below the mine in hopes of detecting any surface water quality degradation resulting from the operation. Although the results of chemical analyses indicated clean water at the time of sampling, diatom diversity was somewhat depressed due to dominance of a metals resistant Achnanthes species (53.1 PRA). This suggests a possible metals problem at an earlier date or on an intermittent basis. The invertebrate population appeared healthy although field examination is not sufficient to detect minor stress.

31. North Fork Flint Creek above Golden Jubilee Mine - Samples were collected about 100 yards above the active mine site. Detectable chemical and physical differences noted here were slightly lower dissolved solids and iron concentrations than the lower station. The downstream increase may be natural in origin and causes no immediate concern since the levels observed at the lower site also indicated high quality water. Mercury concentrations detected here were, surprisingly, higher than below the mine, but still below toxic levels. These traces may have originated from numerous historic mining activity above this point, such as the Red Lion Mine. Diatom diversity was higher here than below and suggests more favorable conditions and Achnanthes species resumed a more normal relative abundance (14.9 PRA). Aquatic invertebrates were plentiful.

Red Lion (Upper North Fork Flint Creek) District field observations - Several small volume groundwater seeps which reach the North Fork were located in the vicinity of the abandoned Red Lion Mine. Field pH and specific conductance determinations indicated low dissolved solids and neutral pH waters hence samples were not collected. After noting the mercury value for station 31, which was about 1 mile below the mine and below the point these seeps entered the North Fork, the actual chemical quality of them remains questionable. Dilution by the North Fork could have lowered metals concentrations of the seeps to near or below detection limits. A Montana Bureau of Mines and Geology report (Earll, 1972) mentions that the Milwaukee Gold Extraction

Company purchased the Red Lion properties in 1901 and built a 100-ton amalgamation and cyanidation mill and town site on the east side of the road, presumably where the current ruins stand. Although very little ore ever reached the mill, the amalgamation process, which utilized mercury, may have been the ultimate source of detectable mercury in the North Fork of Flint Creek.

B. Warm Springs Creek Drainage

32. Cable Creek near mouth - Cable Creek near its mouth was a meandering meadow-type stream with grassy banks. It flowed through swampy hay fields. The bottom material was a thick layer of sediment and organic material. Despite very heavy historical activity including both lode and placer mining, chemical analysis indicated that Cable Creek at this location and time of sampling was apparently unaffected by mine-caused pollution. Periphyton consisted of a varied flora of water crowfoot (*Ranunculus*), three genera of green algae and a diatom association dominated by species of *Fragilaria*, which is an indicator of cool waters. A relatively low PRA of *Achnanthes* species (3.4 PRA) which may suggest occasionally depressed levels of dissolved oxygen was probably due to the anaerobic nature of the stream bottom. A low PRA of *Achnanthes* and other attached species may also signify unstable substrates. The diatom diversity of 2.78 indicates slight stress, perhaps resulting in part from an inadequate dissolved oxygen supply and/or sedimentation problems. Aquatic invertebrates were not overly abundant but several small trout were observed.

33. West (unnamed) tributary Cable Creek below Cable Mine - This small tributary contributed a minor percentage of the total flow to Cable Creek at the time of observation. The stream course ran through a washed out settling pond, an old mill and placer tailings below the legendary Atlantic Cable Lode Mine, the first and one of the most important lode discoveries of the Southern Flint Creek Range Field observations indicated seasonal sedimentation problems in the stream resulting from the tailings. In all but the swiftest areas, the stream bed was blanketed with silt

and sand. Indeed, this tributary may have been a major contributor of the silt accumulations observed in lower Cable Creek. Chemical analysis of the water collected here showed lower total dissolved solids but higher metals levels than the lower station. Iron was the only metal found in concentrations capable of affecting aquatic life (.20mg/1). No evidence of acid mine drainage was noted since pHs and sulfate were normal and no ferric hydroxide (yellowboy) was observed coating the stream bed. Diatom diversity was relatively high at 3.72 indicating a favorable environment. However, the low PRA of Achnanthes species (6.8) may suggest a substrate unsuitable for attached forms, or occasionally depressed dissolved oxygen. Aquatic invertebrates were also scarce due to the poor substrate.

34. Warm Springs Creek above confluence of Cable Creek - Warm Springs Creek is one of two major tributaries whose confluence mark the beginnings of the Clark Fork of the Columbia River. At this site, located near highway 10A, the stream was running swift, cold and clear. No indications of any type of chemical, physical or biological stress were present. Chemical quality was excellent while periphyton and aquatic invertebrates were both abundant and diverse. Indicators of cool, well-oxygenated water dominated the flora and fauna. Substrate consisted of cobbles, boulders and coarse granitic sand.

Hidden Lake (Upper Warm Springs Creek) District field observations - The Hidden Lake District was surveyed on foot. Past activity has been significant as noted from numerous and extensive tailings piles and abandoned buildings. Fortunately, the area was quite dry and no surface waters were seen contacting tailings nor were any mine seeps located. One very large accumulation of mine waste occurred at the Hidden Lake mine together with what appeared to be an old settling basin. Erosion of the tails from snowmelt and rain was evident from the numerous gulleys and troughs cut through them. Whether this seasonal runoff occasionally finds its way to Warm Springs Creek remains unknown.

35. Foster Creek near mouth - A small tributary of Warm Springs Creek in steep heavily timbered country, Foster Creek was, by most indications, of high quality. Metals were all below detectable levels, with the exception of mercury which, although below a toxic concentration, was the highest value observed at all the stations sampled. Although mining activity adjacent to the drainage has been significant, the literature mentions no pan amalgamation operations ever occurring here. Thus, the origin of mercury in this watershed is unknown. Periphyton community structure and invertebrate examination indicated suitable conditions and an unstressed environment.

C. Clark Fork River Drainage

36. Lower Lost Creek - Lost Creek is a small tributary of the Clark Fork River. The flow of the stream at this site was substantially less than the upper reaches due to irrigation usage. Chemical analysis indicated a reasonably clean stream at this point. Arsenic, iron, manganese and silver were all detectable in trace quantities but only silver occurred in a concentration capable of harming freshwater aquatic life (.005 mg/1). Despite this fact, the periphyton and invertebrate community appeared to be thriving.

37. Upper Lost Creek - A comparison of water quality measured at this site some 7 miles upstream showed the silver concentration to be identical to the lower station. Because of very poor roads, the headwaters region and several abandoned mines above this point were not surveyed. Therefore, the moderately high silver levels observed in Lost Creek cannot conclusively be considered as normal background concentrations. While the iron level was also roughly equal to the lower station, arsenic and manganese were below detection limits at this station. Several abandoned mines and a mill were inspected between the upper and lower stations and no impacts to the water quality of the creek were observed. The arsenic and manganese detected at the lower station apparently originated from other sources.

Periphyton and invertebrates in upper Lost Creek appeared unstressed.

38. Antelope Creek above mouth - About a mile below the point of sample collection, this small creek went entirely dry from dewatering due to irrigation usage. Results of chemical analysis showed a very high total phosphate level (2.2 mg/1) and silver and iron in concentrations capable of adversely affecting freshwater aquatic life. Suspended solids were higher in Antelope Creek than most streams surveyed in the Flint Creek Range and the streambed was covered with silt. Since no mining influence could be ascertained from field observations, it is felt that the apparent sedimentation problem and high total phosphorus content are related to agriculture rather than mining. The iron and silver concentrations may very well be normal background levels associated with the local geology. Periphyton and aquatic invertebrate examination depicted "normal", apparently healthy communities.

39. Modesty Creek at Galen - This was not an ideal location to assess the quality of Modesty Creek since it may reflect irrigation returns and/or groundwater recharge. Dissolved solids were measured at one of the higher concentrations seen during the study. Silver was again above levels capable of affecting freshwater aquatic life and arsenic was above normal background levels for streams of the range but below a toxic concentration. The source of the latter is unknown. Periphyton and invertebrates indicated favorable conditions.

40. Racetrack Creek at county road bridge - One of the larger east-side tributaries, Racetrack Creek was, by all indications, a very high quality stream. All metals levels were below or just at detection limits. Total dissolved solids and suspended solids were also very low. Diatom diversity was one of the highest observed in the range and invertebrates were plentiful and varied. The Danielsville Mining District had apparently not left lasting affects on the stream.

41. North Fork Racetrack Creek near mouth - More of a waterfall than a creek, the North Fork drains several high alpine lakes near the headwaters of Racetrack Creek.

Water quality at this site was again exceptional. Metals were all below detection limits. Periphyton community structure and aquatic invertebrate examination indicated a pristine and unperturbed habitat.

42. Pozega Creek at mouth - Another Racetrack Creek tributary, Pozega drains the Pozega Lakes area. Small-scale tungsten mining and exploration in the lakes region has apparently not affected water quality of the creek at the site of examination. Although silver exceeded levels capable of affecting freshwater aquatic life, several other streams draining the same general area have similarly high levels (Lost Creek, Antelope Creek and Modesty Creek). This may indicate, as mentioned for Antelope Creek, normal background levels resulting from the local geology. Other parameters, including periphyton community structure, characterize Pozega Creek as lacking any man-caused impact.

43. Dempsey Creek at Perkins Ranch - Due to poor access, the headwaters of Dempsey Creek were not examined for mines. However, none are shown on available maps and prospecting is thought be have been minimal. Water quality determinations show a very healthy, low-dissolved solids stream with no hint of mining related degradation.

44. Powell Creek below Powell Lake - This creek was nearly dry when sampled. All determinations performed on Powell Creek indicate a highly-oxygenated, cold, clear mountain stream with no detectable pollution.

45. Tin Cup Joe Creek above Tin Cup Lake - As one would hope for in a municipal water supply, Tin Cup Joe Creek contained excellent quality, low dissolved solids water. Diatom diversity was quite high (4.12) and invertebrates were plentiful. Mining activity has been minimal in and adjacent to the drainage.

46. Rock Creek above Rock Creek Lake - Rock Creek at this station was a very swift good-sized stream. As with most other tributaries draining the west side of the range, water quality was again very high. Metals were all just at or below detection

limits with the exception of iron (.03 mg/l) which was still well below toxic levels. Periphyton analysis pointed to conditions typical of an undisturbed cold, clear, well oxygenated mountain stream. Invertebrate examination supported the same observations.

47. Gold Creek below Master Mine - The Gold Creek drainage has been the site of major placer and hard rock mining. Extensive placer tailings of the Pineau Placer, Master Mine and others have created significant erosional potential. Samples collected in July, however, during lower flows, reflected no mining-related degradation. Suspended solids were practically nonexistent and metals were all below detectable levels. The simple aquatic flora at this station consisted mostly of the green alga *Tetraspora* and a sparse diatom association dominated by *Gomphonema olivaceoides* (60.9 PRA). These two taxa are typical of low nutrient, high elevation, cool mountain streams. Since metals were below detection limits, the slight stress here is probably due to the general austerity of the aquatic environment. Conditions during runoff may have been drastically different due to sedimentation.

48. Pikes Peak Creek below mine seep - This station near the headwaters of the drainage was located below several mines. Chemical quality of this water was very similar to that observed in Gold Creek. Metals were below detection limits with the exception of manganese which fell just at detection. Suspended solids were likewise low. The Periphyton community, however, differed significantly from Gold Creek. Pikes Peak Creek at this site had a varied and healthy flora of moss, green and blue-green algae and diatoms. The only aspect of the flora indicating stress was the preponderance of *Achnanthes minutissima* (60.8 PRA) in the diatom association, which effectively suppressed diversity ($\bar{d}$) to 2.57. Since metals were obviously not a problem, the source of stress remains unknown. Aquatic invertebrates were noticeably abundant.

49. Seep from adit above upper Pikes Peak Creek - A small mine located on Emery

Ridge was found to be discharging water at about 25 gallons per minute down the hillside to Pikes Peak Creek. Chemical analysis revealed a relatively high total dissolved solids level when compared to similar seeps throughout the range. Additionally, total phosphorus levels were out of the ordinary when compared to the rest of the Pikes Peak drainage. A rather high .06 mg/1 total phosphorus concentration probably resulted when the groundwater reservoir which fed the seep contacted a portion of the phosphate belt. Pikes Peak Creek itself apparently contacts the deposit to a much smaller degree since total phosphorus values ran on the order of 5 to 6 times less. All metals concentrations measured in the seep water were just at or below detection limits. The aquatic flora consisted of only one genus of non-diatom algae: the green alga Tetraspora. And again, Achnanthes minutissima was the dominant diatom (65.3 PRA) followed by other diatom taxa which, like Tetraspora, are indicators of cool water habitats. Some unnatural stress appeared to be limiting algal diversity and invertebrate proliferation.

50. Dunkelberg Creek near mouth - Although by no means grossly polluted, Dunkelberg Creek near its mouth displayed some evidence of mining impacts. Sulfate concentrations were well above normal background levels for streams of the Flint Creek Range. Arsenic, iron, zinc and manganese were all above detection limits. The iron and zinc levels may have been sufficient to cause some impairment of freshwater aquatic life. Periphyton scrapings contained only one genus of nondiatom algae (Phormidium) and a diatom flora dominated by Nitzschia epiphytica (48.0 PRA). Bahls (1973) reported N. epiphytica to be significantly correlated with high ammonia and phosphate concentrations in the East Gallatin River below the Bozeman wastewater discharge. Total phosphorus was high for the range (.06 mg/1) but not excessive from a biological standpoint. Therefore, it is concluded that the stress in effect here was derived from some form of nitrogen enrichment, perhaps agricultural in origin

51. Dunkelberg Creek below Forest Rose Mine - One of two more important mines within the Dunkelberg mining district, the Forest Rose lies at the extreme head of the drainage. In fact, the initial flow in Dunkelberg Creek originates from seeps below tailings of the Forest Rose Mine. At this point, as one would expect, mining impacts to the surface water are again visible. Sulfate levels were nearly four times those measured at the mouth of the creek. Zinc levels were well within the range capable of suppressing freshwater aquatic life and mercury was measured as the second highest concentration found at all stations, although still below toxic levels. At least some small scale smelting has been done in the Dunkelberg District (Pardee 1917) but the actual location of the operation and whether or not pan amalgamation concentrating methods were utilized is unknown. The mercury found at this site may have originated from such a source. Arsenic, iron and manganese values for this site were significantly lower than those found in samples collected near the mouth. Aquatic flora found below the Forest Rose Mine was a typically "clean water" association of *Vaucheria*, moss and a diatom association dominated by *Achnanthes* species. *Diatoma hiemale* was also a significant component of the diatom assemblage (10.5 PRA) indicating a consistently cold water habitat. Despite the occurrence of clean water indicators, diatom diversity and the number of diatom taxa were somewhat depressed. While zinc and possibly other metals in sublethal amounts may have contributed to the stress exhibited here, at least some of the stress was thermal in origin. The aquatic invertebrate community observed here likewise appeared to be under some degree of stress.

Table 2. Summary - Chemical and physical water quality data for streams of the Flint Creek Range.

Station Location	Agency	Date	Flow (cfs)	Water Temp (°C)	pH	Conductivity (umhos)	Turbidity (JTU'S)	TSS	SO_4	Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
										Concentration (mg/l)													
I. Flint Creek Drainage																							
Barnes Creek near mouth 10N 12W Sec 30 CAC	WQB(1)	8/17/78	3.0	9.5	8.12	676.0		842.0	124.0	<.005$_1$	.003$_1$	<.001$_1$	<.01$_1$	.57$_1$	<.0002$_1$	.082$_1$	<.005$_1$	<.005$_1$				.149	
Douglas Creek at mouth 9N 13W Sec 10 ACC	WQB(2)	7/13/78	5.6	11.0	8.13	286.0		9.1	14.6	<.005$_1$	.003$_1$	<.001$_1$	<.01$_1$	.15$_1$	<.0002$_1$	.025$_1$	<.005$_1$	<.005$_1$				.057	
Douglas Creek below seep from adit 9N 12W Sec 31 DCC	WQB(3)	7/13/78	10.5	9.0	8.62	210.0		3.7	7.3	.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	.03$_1$	<.0002$_1$	.005$_1$	<.005$_1$	.015$_1$				.026	
Seep from adit to Douglas Creek 9N 12W Sec 31 DCA	WQB(4)	7/13/78	1.5	9.2	8.07	225.0			11.2	<.005$_1$	.003$_1$	<.001$_1$	<.01$_1$	<.01$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.017	
Douglas Creek below confluence north & middle forks 9N 12W Sec 31 DA	USFS	8/26/76	10. (E)	2.2	7.94	218.1			9.0					<.01$_2$		<.01$_2$				.081			
" "	USFS	5/13/77	2.6	2.8	8.17	243.0		7.9	10.6					<.01$_2$		<.01$_2$				.188			
" "	USFS	7/1/77	7.4	10.0	8.21	243.3		20.1	21.8					<.01$_2$		<.01$_2$				.163			
" "	WQB(5)	7/13/78	9.0	8.5	8.61	208.0		3.6	6.7	<.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	.02$_1$	<.0002$_1$	.005$_1$	<.005$_1$	.018$_1$				.027	
North Fork Douglas Creek at mouth 9N 12W Sec 32 CBB	WQB(6)	7/20/78	.8	10.0	8.56	237.0		6.0	20.5	<.005$_1$	.001$_1$	.002$_1$	<.01$_1$	.08$_1$	<.0002$_1$	.015$_1$	<.005$_1$	.110$_1$				.024	
North Fork Douglas Creek .5 mile below mine 9N 12W Sec 27 CD	WQB(7)	7/20/78		6.0	8.46	319.0		<4.3	123.0	<.005$_1$	.001$_1$	.004$_1$	<.01$_1$	.02$_1$	<.0002$_1$	.030$_1$	<.005$_1$	1.3$_1$				.013	
North Fork Douglas Creek just below mine 9N 12W Sec 34 BAB	WQB(8)	8/18/78	.06 (E)	9.0	8.02	407.3		13.6	115.0	<.005$_1$	.003$_1$	.041$_1$	.04$_1$	1.0$_1$	<.0002$_1$	.150$_1$	<.005$_1$	3.2$_1$				.003	
Middle Fork Douglas Creek at mouth 9N 12W Sec 32 CBA	WQB(9)	7/20/78	9.0	6.0	8.51	192.0		<2.8	4.8	<.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	<.01$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.023	

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (oC)	pH	Conductivity (umhos)	Turbidity (JTU'S)	TSS	SO_4	Ag	As	Concentration (mg/1) Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+NO_2	NO_3	$O-PO_4$	TOT P	TOT NH_3
Seep from adit above Middle Fork Douglas Creek 8N 12W Sec 4 AA	WQB(10)	7/20/78	1.8	7.0	7.73	116.3		6.5	7.8	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	<.01$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.050	
Gird Creek near mouth 13N 9W Sec 27 CDC	WQB(11)	7/13/78	1.0	11.0	8.25	271.0		20.4	6.0	<.005$_1$	.003$_1$	<.001$_1$	<.01$_1$	.20$_1$	<.0002$_1$	.015$_1$	<.005$_1$	<.005$_1$				.053	
Boulder Creek near mouth 8N 13W Sec 4 CDA	WQB	3/27/74	20.0	2.2		196.0	<.9					<.01$_1$	<.01$_1$	.04$_1$		.01$_1$		.01$_1$					
" "	USFS	5/29/75		.7	8.15	169.2			10.5					.14$_3$		.00$_2$				.2			
" "	"	6/6/75		4.0	7.3	70. (F)																	
" "	"	6/11/75		4.0	7.0		6.0 (F)																
" "	"	6/18/75		3.0	8.2		21.0 (F)																
" "	"	7/1/75		3.0	7.4		1.0 (F)																
" "	"	7/10/75		8.0	7.8	79.0 (F)	3.2 (F)																
" "	"	7/17/75			7.8	108.0 (F)	2.0 (F)																
" "	"	9/24/75		4.0	6.45	185.5			7.7					<.01$_3$		<.01$_2$				.045			
" "	"	6/10/76		8.0	7.45	81.5	4.5 (F)	18.5	3.5					.01$_2$		.01$_2$				.036			
" "	"	7/14/76		11.0	8.0	149.0 (F)	2.0 (F)	6.7															
" "	"	10/26/76		3.0	8.33	196.8	1.0 (F)		6.6					<.01$_2$		<.01$_2$				.075			
" "	"	9/16/77		10.0	8.33	204.6	.4 (F)		7.2					<.01$_2$		<.01$_2$				.038			
" "	WQB(12)	7/7/78	109.0	9.0	7.80	83.4		<10.6	1.5	<.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	.15$_1$	<.0002$_1$	.010$_1$	<.005$_1$	.010$_1$				.023	
South Boulder Creek near mouth 8N 13W SEC 22 CAD	WQB(13)	7/11/78	4.8	12.0	7.35	58.0		14.1	3.2	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	.40$_1$	<.0002$_1$	.015$_1$	<.005$_1$	<.005$_1$				.023	

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (oC)	pH	Conduc-tivity (umhos)	Tur-bidity (JTU'S)	TSS	SO4	Concentration (mg/1) Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+ NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
Wyman Creek above South Boulder Creek 8N 13W Sec 22 CAC	WQB(14)	7/11/78	2.0	13.5	8.22	319.0		9.6	7.2	$<.005_1$	$.003_1$	$<.001_1$	$.03_1$	$.15_1$	$<.0002_1$	$.015_1$	$<.005_1$	$<.005_1$				.044	
Wyman Creek (Storet Data-not located)																							
Princeton Gulch Creek near mouth 8N 13W Sec 25 ACD	WQB(15)	7/7/78	.5	7.0	8.20	176.0		10.2	1.8	$<.005_1$	$.001_1$	$<.001_1$	$<.01_1$	$.04_1$	$<.0002_1$	$.010_1$	$<.005_1$	$<.005_1$				.027	
Swamp Gulch Creek near mouth 8N 13W Sec 36 BAA	WQB(16)	7/7/78	4.0	9.5	7.40	25.8		15.7	1.8	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$.31_1$	$<.0002_1$	$<.01_1$	$<.005_1$	$<.005_1$				.025	
Copper Creek 1 mile above mouth 7N 12W Sec 5 CBC	WQB(17)	7/12/78	21.8	9.0	7.53	37.0		<6.3	2.5	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$.07_1$	$<.0002_1$	$.010_1$	$<.005_1$	$<.005_1$				.008	
Royal Gold Creek near mouth 8N 12W Sec 31 DAA	WQB(18)	7/12/78	6.5	8.5	7.33	46.0		3.7	2.9	$<.005_1$	$<.001_1$	$.001_1$	$<.01_1$	$.14_1$	$<.0002_1$	$.015_1$	$.013_1$	$.030_1$				.015	
Little Gold Creek 1 mile above mouth 8N 12 W Sec 29 CDB	WQB(19)	7/7/78	20.5	7.0	7.40	38.4		<10.4	1.5	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$.08_1$	$<.0002_1$	$<.01_1$	$<.005_1$	$<.005_1$				.020	
Seep from tailings pond to Boulder Creek 12N 8W Sec 32 CCC	WQB(20)	7/12/78	.3	8.5	7.85	145,0			9.1	$<.005_1$	$.032_1$	$.001_1$	$.04_1$	2.1_1	$<.0002_1$	$.030_1$	$.190_1$	$.430_1$					
Boulder Creek below Brooklyn Mine 7N 12W Sec 5 BAD	WQB(21)	7/12/78	31.8	8.0	7.79	102.0		<4.2	3.1	$<.005_1$	$.002_1$	$<.001_1$	$<.01_1$	$.13_1$	$<.0002_1$	$<.005_1$	$<.005_1$	$.008_1$				.008	
Boulder Creek above Brooklyn Mine 7N 12W Sec 9 BBB	WQB(22)	7/12/78	31.8	8.0	7.82	99.0		3.7	2.9	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$.03_1$	$<.0002_1$	$<.005_1$	$<.005_1$	$.005_1$				.007	
Granite Creek near mouth 7N 12W Sec 9 AAB	USFS	9/21/77		4.0	8.11	143.5	.45 (F)		.1					$<.01_2$		$<.01_2$				.025			
Granite Creek near mouth 7N 12W Sec 9 BAC	WQB(23)	7/12/78		7.5	7.79	104.0		<5.0	2.9	$<.005_1$	$.001_1$	$<.001_1$	$<.01_1$	$.09_1$	$<.0002_1$	$<.005_1$	$<.005_1$	$.013_1$				.025	

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (°C)	pH	Conductivity (umhos)	Turbidity (JTU'S)	TSS	SO_4	Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+ NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
								Concentration (mg/l)															
Camp Creek above Philipsburg 7N 14W Sec 25 ADD	WQB(24)	8/18/78	1.0	9.0	8.66	654.9		4.7	206.0	<.005$_1$	.011$_1$	<.001$_1$	<.01$_1$	.06$_1$	<.0002$_1$	.064$_1$	<.005$_1$	.050$_1$				.014	
Douglas Creek below tailings at Philipsburg 7N 14W Sec 36 ABD	WQB	6/2/77	.8		7.50	417.8	66.	83.	89.0		1.81 .072	<.005$_1$ <.005$_2$	.04$_1$ .02$_2$	2.5$_1$	<.0002$_1$ <.0002$_2$	7.2$_1$ 6.6$_2$	.12$_1$ <.05$_2$	1.3$_1$ .82$_2$					
" "	WQB(25)	8/18/78	2.2	11.5	6.95	324.4		8.9	129.0	<.005$_1$	.13$_1$	.008$_1$	<.03$_1$	.57$_1$	<.0002$_1$	5.5$_1$	.022$_1$	1.7$_1$				.023	
Fred Burr Creek below Rumsey 6N 13W Sec 7 ADD	WQB(26)	8/9/78	5.0	16.0	7.54	51.0		<3.3	3.6	<.005$_1$	.023$_1$	<.001$_1$	<.01$_1$	.08$_1$	<.0002$_1$	.035$_1$	<.005$_1$	<.008$_1$				.006	
Fred Burr Creek above Rumsey 6N 13W Sec 8 AAC	WQB(27)	8/9/78	5.2	14.0	7.62	47.0		<2.6	3.5	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	.02$_1$	<.0002$_1$	.005$_1$	<.005$_1$	<.005$_1$				.005	
Spring Creek (Summer Gulch) near mouth 6N 14W Sec 15 DAD	WQB(28)	8/17/78	3.5	10.0	7.94	231.8		8.6	5.7	<.005$_1$	.003$_1$	<.001$_1$	<.01$_1$	.11$_1$	<.0002$_1$	.064$_1$	<.005$_1$	<.005$_1$				.052	
North Fork Flint Creek near mouth 5N 13W Sec 5 C	USFS	9/8/76	30.0 (E)	1.7	8.17	216.8			4.4					.04$_2$		<.01$_2$				.041			
" "	"	5/9/77	15.0	3.3	8.08	200.8		23.1	4.5					.04$_2$		<.01$_2$				.036			
" "	"	6/29/77	9.7	10.0	8.25	199.7		1.5	4.7					.02$_2$		<.01$_2$				.059			
" "	WQB(29)	8/9/78	5.2	9.0	8.24	221.0		8.6	3.5	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	.06$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.005	
North Fork Flint Creek above mouth 6N 13W Sec 34	USFS	9/16/77	1.2	6.0	8.32	186.9	.40 (E)		3.3					<.01$_2$		<.01$_2$				.038			
North Fork Flint Creek below Golden Jubilee Mine 6N 13W Sec 22 DDB	WQB(30)	8/9/78	5.0	10.0	8.43	201.0		<2.6	2.9	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	.03$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.002	
North Fork Flint Creek above Golden Jubilee Mine 6N 13W Sec 14 CAC	WQB(31)	8/9/78	5.0	8.0	8.22	162.0		5.1	2.8	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	<.01$_1$	.0005$_1$	<.005$_1$	< .005$_1$	<.005$_1$				.002	
II. Warm Springs Creek Drainage																							
Cable Creek near mouth 5N 13 W Sec 23 ADA	WQB(32)	8/10/78	6.0		8.16	315.0		< 2.7	11.9	<.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	.13$_1$	<.0002$_1$	.010$_1$	<.005$_1$	<.005$_1$				.009	

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (°C)	pH	Conductivity (umhos)	Turbidity (JTU'S)	TSS	SO_4	Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
									Concentration (mg/1)														
West tributary Cable Creek below Cable Mine 5N 13W Sec 10 DCD	WQB(33)	8/10/78	.03		7.71	150.0		< 4.4	10.2	<.005$_1$	.002$_1$	<.001$_1$	.02$_1$	.20$_1$	<.0002$_1$	.13$_1$	<.005$_1$	<.005$_1$				.009	
Upper Warm Springs Creek 5N 13W Sec 1 CBB	USFS	9/8/76	40.0 (E)	2.8	8.00	161.8			5.0					<.01$_2$		<.01$_2$				.056			
" "	"	5/9/77	37.7	5.6	8.03	139.4		12.8	4.4					<.01$_2$		<.01$_2$				.036			
" "	"	6/29/77	14.0	5.6	8.15	158.8		14.8	4.2					<.01$_2$		<.01$_2$				.029			
Warm Springs Creek above confluence Cable Creek 5N 12W Sec 19 BCD	WQB(34)	8/10/78	17.0	9.0	8.03	199.0		<2.5	4.4	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	.04$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.009	
Foster Creek above mouth 5N 12W Sec 17 CAC	USFS	9/3/76	20.0 (E)	3.9	8.01	175.2			7.17					<.01$_2$		<.01$_2$				.043			
" "	"	5/9/77	17.2	11.1	8.18	152.9		2.6	8.1					<.01$_2$		<.01$_2$				<.023			
Foster Creek near mouth 5N 12W Sec 20 ACB	WQB(35)	9/13/78	8.0 (E)	7.0	8.14	177.1		< 2.7	6.6	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	<.01$_1$	.0038$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.01	
III. Clark Fork River Drainage																							
Lost Creek at Dempsey 5N 9W Sec 6 ACA	Westech	8/24/78	29.3	17.7		638.0						<.01$_3$	.02$_3$					.02$_3$					
" "	"	10/5/78	52.8	6.0		567.4			188.0														
" "	"	11/16/78	50.0	1.0	8.10	590.0			123.0				.01$_1$					.005$_1$	.60		<.001	.01	<.01
Lost Creek at HW crossing 5N 10W Sec 29 BBC	WQB(36)	9/13/78	5.0 (E)	10.0	8.20	252.9		3.5	14.3	.005$_1$	.007$_1$	<.001$_1$	<.01$_1$	.07$_1$	<.0002$_1$	.010$_1$	<.005$_1$	<.005$_1$				<.01	
Upper Lost Creek 5N 11W Sec 6 ACA	WQB(37)	9/13/78	13.4	6.0	8.16	163.9		<2.7	6.3	.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	.08$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				<.01	
Antelope Creek 5N 11W Sec 1 CCD	WQB(38)	9/14/78	1.0 (E)	8.0	8.29	388.3		35.4	43.8	.010$_1$	.004$_1$	<.001$_1$	<.01$_1$	.27$_1$	<.0002$_1$	.019$_1$	<.005$_1$	<.005$_1$				2.2	
Modesty Creek at Galen 6N 9W Sec 31 BBA	WQB(39)	9/14/78	9.8	7.0	8.12	533.9		<2.9	35.9	.005$_1$	.029$_1$	<.001$_1$	.01$_1$	.03$_1$		.014$_1$	<.005$_1$	<.005$_1$					
Racetrack Creek near mouth 5N 9W Sec 9 CCC	Westech	10/5/78	36.2	8.0		355.5			54.7														

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (°C)	pH	Conductivity (umhos)	Turbidity (JTU'S)	TSS	SO_4	Concentration (mg/l)													
										Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
Racetrack Creek near mouth 5N 9W Sec 9 CCC	Westech	11/16/78	18.6	1.0	7.80	76.0			9.9			<.01$_1$						.005$_1$	.11		<.001	<.01	<.01
Racetrack Creek at Dempsey (HW 10) 6N 9W Sec 8 DDB	EPA**	10/6/70 to 11/7/70		3.9 (6)	7.37 (6)	252.5 (6)	1.0 (6)	2.2 (6)	14.0 (3)		.005 (6)	.010 (6)3	.022 (5)2 .031 (6)3	.107 (5)2 .174 (6)3	.001 (6)3		.125 (6)3	.017 (4)2 .038 (6)3					
" "	WQB	7/15/76	2.4	12.8	7.75	211.2													.08		.01	.015	<.01
Racetrack Creek at county road bridge 6N 11W Sec 13 AB	USFS	8/25/76	60.0 (E)	8.3	7.59	86.8	51.0 (F)		5.12					.01$_2$		<.01$_2$				.027			
" "	"	5/10/77	20.8	3.3	7.39	73.9		3.7	5.40					.04$_2$		<.01$_2$				.036			
" "	"	6/30/77	47.5	10.0	7.64	79.2		3.4	5.9					.01$_2$		<.01$_2$				.027			
" "	WQB[40]	9/14/78	>20.0 (E)	7.0	7.60	86.1		<2.6	5.1	<.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	<.01$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				<.01	
North Fork Racetrack Creek at mouth 7N 12W Sec 35 DDA	WQB[41]	9/14/78	7.0 (E)	5.0	7.68	70.9		<2.6	3.8	<.005$_1$	<.001$_1$	<.001$_1$	<.01$_1$	<.01$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				<.01	
Pozega Creek at mouth 6N 12W Sec 1 CAA	WQB[42]	9/14/78	10.0 (E)	6.5	7.18	33.7		<2.7	2.5	.010$_1$	<.001$_1$	<.001$_1$	<.01$_1$	.02$_1$	<.0002$_1$	.005$_1$	<.005$_1$	<.005$_1$				<.01	
Dempsey Creek at mouth	EPA**	8/11/70 to 9/17/70		12.5 (4)	7.55 (4)	748.7 (4)		1.0 (4)			.008 (4)3	.010 (2)3	.032 (4)2 .048 (4)3	.080 (4)2 .075 (4)3	.008 (4)3	.060 (4)1 .045 (4)2	.075 (4)2 .075 (4)3	.042 (4)2 .108 (4)3					
Dempsey Creek at County road bridge 7N 9W Sec 33 CAA	Westech	11/16/78	9.1	2.5	8.00	395.0			42.8				<.01$_1$					.008$_1$	.47		.012	.03	<.01
Dempsey Creek at HW 10 7N 9W Sec 32 DDB	WQB	7/15/76	4.9	14.8	8.10	544.8													.08		.031	.055	<.01
Dempsey Creek at Perkins Ranch 6N 10W Sec 4 BBB	WQB[43]	9/29/78	5.0 (E)	6.0	7.50	81.7		.3	6.8	<.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	.04$_1$	<.0002$_1$	.005$_1$	<.005$_1$	<.005$_1$				<.01	
Powell Creek below Powell Lake 7N 10W Sec 17 ACD	WQB[44]	9/29/78	.5 (E)	6.5	7.93	148.2		3.3	10.9	<.005$_1$	.001$_1$	<.001$_1$	<.01$_1$	.02$_1$	<.0002$_1$	<.005$_1$	<.005$_1$	<.005$_1$				.04	

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (°C)	pH	Conductivity (umhos)	Turbidity (JTU'S)	TSS	SO_4	Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+ NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
									Concentration (mg/l)														
Tin Cup Joe Creek above Tin Cup Lake 7N 10W Sec 9 BAA	WQB(45)	9/29/78	8.0 (E)	6.0	7.50	60.6		< 2.3	3.3	$<.005_1$	$.001_1$	$<.001_1$	$<.01_1$	$.07_1$	$<.0002_1$	$<.005_1$	$<.005_1$	$<.005_1$				.06	
Rock Creek above Rock Creek Lake 8N 11W Sec 34 ABB	WQB(46)	9/29/78	30.		7.27	49.3		< 2.5	3.5	$<.005_1$	$.001_1$	$<.001_1$	$<.01_1$	$.03_1$	$<.0002_1$	$.005_1$	$<.005_1$	$<.005_1$				<.01	
Gold Creek at mouth 10N 10W 31 Sec 31 BBB	MF & G	4/19/78	20.0 (E)		8.2	453.1			74.0										.11		.058	.074	.02
" "	"	5/24/78		8.3	8.5	417.1			50.4										.03		.089	.11	<.01
" "	"	8/23/78	27.0	16.0	8.63	500.6			8.2										.01		.123	.15	.02
" "	"	11/15/78	26.6	0.0	8.3	350.0			49.4				$.01_1$					$<.005_1$	.03		.053	.06	<.01
Gold Creek 7 miles above mouth 9N 11W Sec 29 DC	WQB	9/29/75	17.6		7.85	170.0			12.0			$<.001_1$ $<.001_2$ $<.001_3$		$.08_1$ $.08_3$	$<.0002_1$ $<.0002_3$			$<.01_1$ $.05_2$ $.06_3$	.04		.011	.019	
Gold Creek near Gold Creek 9N 11W Sec 31 BBB	Westech	10/6/78	43.9	7.2		382.6			44.1														
Upper Gold Creek 9N 11W Sec 32 BDA	USFS	6/17/76	170.0 (E)	5.6	8.2	30.0	1.6	16.0															
" "	"	7/13/76	120.0 (E)	6.7	8.3	84.0	.7	3.8															
" "	"	8/12/76		6.1	7.92	131.5	.2		5.6	$<.01_2$	$<.002_2$	$<.01_2$	$<.01_2$	$.04_2$		$<.01_2$	$.16_2$	$.02_2$		.04			
" "	"	5/12/77	26.2	5.6	7.64	103.0		4.0	6.1					$.01_2$		$<.01_2$				.03			
" "	"	7/6/77	21.2	4.4	7.98	114.1		6.8	6.7					$<.01_2$		$<.01_2$				.08			
Gold Creek below Master Mine 8N 12W Sec 1 DCA	WQB	9/29/75	17.6		7.85	170.0	2.6		12.0		$<.001_1$ $<.001_2$ $<.001_3$			$.08_1$ $.08_3$	$<.0002_1$ $<.0002_3$	$<.01_1$ $.02_3$		$<.01_1$ $.05_2$ $.06_3$	.04		.011	.019	
Gold Creek below Master Mine 8N 12W Sec 1A	WQB(47)	7/20/78	19.0		7.77	82.0		< 2.6	3.8	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$<.01_1$	$<.0002_1$	$<.005_1$	$<.005_1$	$<.005_1$				.011	
Gold Creek below Master Mine 7N 12W Sec 1 ACA	USFS	9/13/76								$<.01_2$	$<.002_2$	$<.01_2$		$.02_2$	$<.003_2$		$<.05_2$						
Gold Creek Mine Adit 8N 12W Sec 11 ADA	USFS	7/13/76								$<.01_2$	$<.002_2$	$<.01_2$		$.03_2$	$<.003_2$		$<.05_2$						

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (^oC)	pH	Conductivity (umhos)	Turbidity (JTU's)	TSS	SO_4	Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+ NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
										Concentration (mg/l)													
Gold Creek above Master Mine 8N 12W Sec 11 DDC	USFS	9/13/76								$<.01_2$	$<.002_2$	$<.01_2$		$.03_2$	$<.003_2$		$<.05_2$						
Pikes Peak Creek below mine 8N 11W Sec 9 AD	WQB	9/29/75	3.7		7.40	77.0	1.6		5.0					$.03_1$	$<.0002_1$				.01		.007	.010	
" "	"	1/14/76	2.5	.5	7.77	92.0	.3		9.0										.05		.004	.004	
" "	"	4/21/76	5.5	1.5	7.60	134.0	.1		13.0										.09		.005	.009	
" "	"	5/13/76			7.22	85.5	.3		4.8					$<.01_1$				$<.01_1$	1.0		.004	.020	
Pikes Peak Creek below mine seep 8N 11W Sec 9 DA	WQB(48)	7/20/78		8.0	7.76	60.0		< 6.4	4.2	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$<.01_1$	$<.0002_1$	$.005_1$	$<.005_1$	$<.005_1$				.009	
Seep from adit above upper Pikes Peak Creek 8N 11W Sec 9 AD	WQB(49)	7/20/78	.06 (E)		8.25	327.0		5.2	30.0	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$.10_1$	$<.0002_1$	$.005_1$	$<.005_1$	$.005_1$				.056	
Pikes Peak Creek above mine 8N 11W Sec 9 AD	WQB	9/29/75	3.7		7.40	77.0	1.6		5.0					$.03_1$	$<.0002_1$				.01		.007	.010	
" "	WQB	1/14/76	2.7	.5	7.91	132.0	.3		18.0	$<.01_1$		$<.001_1$		$.01_1$			$<.05_1$	$<.01_1$	.08		.006		
" "	"	4/21/76	5.5	1.5	7.60	134.0	.1		13.0										.09		.005	.009	
" "	"	5/13/76			7.22	85.5	.3		4.8					$<.01_1$				$<.01_1$	1.0		.004	.020	
Blum Creek 9N 11W Sec 19 BBB	USFS	7/14/76	2.0 (E)	7.8	8.20	210.0	1.2	3.0															
" "	"	8/26/78	.5 (E)		8.24	291.2		0.0	14.6					$<.01_2$		$<.01_2$				.041			
Crevice Creek 9N 11W Sec 29 BCD	USFS	7/13/76	4.0 (E)	4.4	8.50	167.0	.6	50.2															
" "	"	8/20/76		6.1	8.20	236.7			10.4					$<.01_2$		$<.01_2$				.050			
Dunkelberg Creek at mouth 10N 12W Sec 36 A	WQB(50)	7/20/78	.3	18.0	8.21	479.0		11.2	45.3	$<.005_1$	$.004_1$	$<.001_1$	$<.01_1$	$.24_1$	$<.0002_1$	$.040_1$	$<.005_1$	$.010_1$				.062	
Dunkelberg Creek above mouth 9N 12W Sec 15 ABD	USFS	6/18/76	8.0	6.7	8.60	160.0	2.6	7.2															
" "	"	8/19/76	5.0 (E)	8.3	8.26	260.2			24.62					$<.01_2$		$<.01_2$				.084			
" "	"	5/12/77	.9	7.8	8.43	301.3		11.4	28.4					$<.01_2$		$<.01_2$				.054			

Table 2 continued.

Station Location	Agency	Date	Flow (cfs)	Water Temp (°C)	pH	Conduc-tivity (umhos)	Tur-bidity (JTU'S)	TSS	SO_4	Concentration (mg/l) Ag	As	Cd	Cu	Fe	Hg	Mn	Pb	Zn	NO_3+ NO_2	NO_3	O-PO_4	TOT P	TOT NH_3
Dunkelberg Creek above mouth 9N 12W Sec 15 ABD	USFS	7/6/77	2.0	7.8	8.22	284.9		9.7	26.5					$<.01_2$		$<.01_2$							
Dunkelberg Creek below Forest Rose Mine 9N 12W Sec 22 DB	WQB(51)	7/20/78	.11		8.06	605.0		<4.2	174.0	$<.005_1$	$<.001_1$	$<.001_1$	$<.01_1$	$.07_1$	$.0013_1$	$.025_1$	$<.005_1$	$.028_1$		.104		.019	
Dunkelberg Creek at Forest Rose Mine 9N 12W Sec 22 DB	USFS	8/12/76	.5 (E)	6.7	8.50	350.0				$<.01_2$	$<.002_2$	$<.01_2$	$.01_2$				$.05_2$	$.49_2$					

WQB(#) - Data collected for this study.
** - Represents mean value for several measurements. Number of measurements in parentheses.
(E) - Estimated flow
(F) - Field determination
1 - Total recoverable form
2 - Dissolved form
3 - Total form

Table 3. Structure of benthic diatom associations in streams draining the Flint Creek Range.

Stream Station and Number	Frustules Counted*	Taxa Counted	Total Taxa	Diversity ($\bar{d}$)	PRA** Achnanthes Species	PRA** Nitzschia Species
(1) Barnes Creek near mouth	331	34	37	3.80	4.8	8.4
(2) Douglas Creek at mouth	438	34	36	5.12	18.3	13.0
(3) Douglas Creek below seep from adit	342	30	33	3.35	20.7	5.1
(4) Seep from adit to upper Douglas Creek	332	12	13	2.20	44.9	0.3
(5) Douglas Creek below confluence North and Middle Forks	343	26	29	3.71	36.7	9.0
(6) North Fork Douglas Creek at mouth	349	23	25	2.90	27.2	1.2
(7) North Fork Douglas Creek .5 mile below Wasa Mine	340	5	7	1.60	47.4	0.0
(8) North Fork Douglas Creek just below Wasa Mine	365	3	3	0.11	98.6	0.3
(9) Middle Fork Douglas Creek at mouth	334	16	16	2.47	53.3	0.6
(10) Seep from adit above Middle Fork Douglas Creek	314	12	13	1.88	26.1	0.0
(11) Gird Creek near mouth	356	40	43	4.50	10.5	20.6
(12) Boulder Creek near mouth	332	39	40	3.42	20.7	3.6
(13) South Boulder Creek near mouth	105	26	26	4.12	12.4	1.9

Table 3 continued.

Stream Station and Number	Frustules Counted*	Taxa Counted	Total Taxa	Diversity ($\bar{d}$)	PRA** Achnanthes Species	PRA** Nitzschia Species
(14) Wyman Creek above confluence with South Boulder Creek	319	35	35	3.72	8.5	7.3
(15) Princeton Creek near mouth	322	31	32	4.09	25.5	7.3
(16) Swamp Creek near mouth	330	41	47	3.40	6.7	2.4
(17) Copper Creek above mouth	111	20	20	3.51	27.9	0.0
(18) Royal Gold Creek above mouth	325	37	42	3.84	10.8	1.8
(19) Little Gold Creek above mouth	374	45	48	4.13	33.5	6.7
(20) Seep from old tailings pond to Boulder Creek	-SAMPLE NOT COLLECTED-					
(21) Boulder Creek below Brooklyn Mine	344	33	35	3.82	21.9	7.6
(22) Boulder Creek above Brooklyn Mine	343	29	29	3.62	45.5	9.7
(23) Granite Creek near mouth	338	30	33	2.79	22.3	1.8
(24) Camp Creek above Philipsburg	336	22	25	2.50	52.4	2.1
(25) Douglas Creek below tailings at Philipsburg	129	11	11	2.44	41.1	8.5
(26) Fred Burr Creek below Rumsey	362	17	21	0.75	93.1	0.9
(27) Fred Burr Creek above Rumsey	353	20	32	2.24	64.7	0.3
(28) Spring Creek (Summer Gulch) near mouth	357	43	54	4.34	7.1	14.0
(29) North Fork Flint Creek near mouth	359	45	52	3.67	25.5	2.5

Table 3 continued.

Stream Station and Number	Frustules Counted*	Taxa Counted	Total Taxa	Diversity ($\bar{d}$)	PRA** Achnanthes Species	PRA** Nitzschia Species
(30) North Fork Flint Creek below Golden Jubille Mine	121	28	28	4.28	14.9	4.1
(31) North Fork Flint Creek above Golden Jubille Mine	322	34	43	3.08	53.1	7.7
(32) Cable Creek near mouth	351	24	43	2.78	3.4	1.2
(33) West (unnamed) tributary Cable Creek below Cable Mine	356	30	36	3.72	6.8	5.6
(34) Warm Springs Creek above confluence Cable Creek	104	32	32	4.33	27.9	12.5
(35) Foster Creek near mouth	373	39	42	3.47	39.1	5.4
(36) Lower Lost Creek	387	46	54	3.82	47.3	7.8
(37) Upper Lost Creek	374	46	50	3.86	9.7	3.6
(38) Antelope Creek above mouth	359	27	31	3.72	17.3	15.9
(39) Modesty Creek at Galen	363	32	39	3.20	48.2	14.2
(40) Racetrack Creek at county road bridge	331	51	60	4.71	17.5	10.5
(41) North Fork Racetrack Creek near mouth	346	45	54	4.32	29.2	6.7
(42) Pozega Creek at mouth	369	31	39	3.38	46.4	0.8
(43) Dempsey Creek at Perkins Ranch	366	51	55	4.67	21.5	7.4
(44) Powell Creek below Powell Lake	348	32	40	3.88	42.3	5.7
(45) Tin Cup Joe Creek above Tin Cup Joe Lake	336	37	44	4.12	15.2	0.9

Table 3 continued.

Stream Station and Number	Frustules Counted*	Taxa Counted	Total Taxa	Diversity ($\bar{d}$)	PRA** Achnanthes Species	PRA** Nitzschia Species
(46) Rock Creek above Rock Creek Lake	318	40	49	4.12	17.3	2.2
(47) Gold Creek below Master Mine	133	21	21	2.53	9.1	4.7
(48) Pikes Peak Creek below mine seep	352	29	45	2.57	67.7	0.6
(49) Seep from adit above upper Pikes Peak Creek	337	12	13	1.87	65.3	9.8
(50) Dunkelberg Creek near mouth	344	14	26	2.36	17.1	48.6
(51) Dunkelberg Creek below Forest Rose Mine	324	20	23	2.50	68.8	5.5

* Only 100-200 frustules were counted if diatoms were sparse; otherwise, in excess of 300 frustules were counted.

** PRA = Percent Relative Abundance

VI SUMMARY

Water Analyses

Chemical/physical analyses performed on samples from 51 stream stations on 37 tributaries draining the Flint Creek Range indicated water quality was generally good during the period of study. Historical and existing mining activities in the range had impacted a small percentage of the surface waters examined. Severely impacted stream segments were rare. Most streams were characterized as having low dissolved and suspended solids levels. And although elevated heavy metals concentrations were observed at some stream stations, the stream biology generally failed to indicate a depression in the health of resident aquatic organisms. This, most likely, was due to the predominance of moderately hard, slightly alkaline waters buffering the effects of metals additions. A review of existing hardness and alkalinity data, which was not included in this report, showed average values to be on the order of 100. As such, some degree of buffering capacity would be provided against moderately low metals levels. Unlike many areas of intense past mining activity such as the Boulder Batholith region, acid mine drainage was not common. The pH measurements ranged from 6.95 to 8.66. The highest sulfate concentration measured was 206.0 mg/l. This value, though not excessive, was well above concentrations detected at most stations and was believed linked to past mining activity. Some streams, especially many draining the northwest corner of the range, contained greater total phosphorus levels than would be expected in similar mountain headwaters. There appeared to be a fairly good correlation between these higher concentrations and the localized occurrence of natural phosphate beds (see Figures 5 & 6). Additionally, several streams draining the eastern portions of the mountains (Lost, Pozega, Antelope and Modesty Creeks) showed relatively high background levels of silver. The source remains unknown, but may have been due to natural geologic conditions rather than mining impacts.

Biological Analyses

The flora of a typical stream in the Flint Creek Range consisted of moss, a few

TOTAL PHOSPHORUS CONCENTRATIONS IN STREAMS OF THE FLINT CREEK RANGE (mg./l. as P)

Figure 5

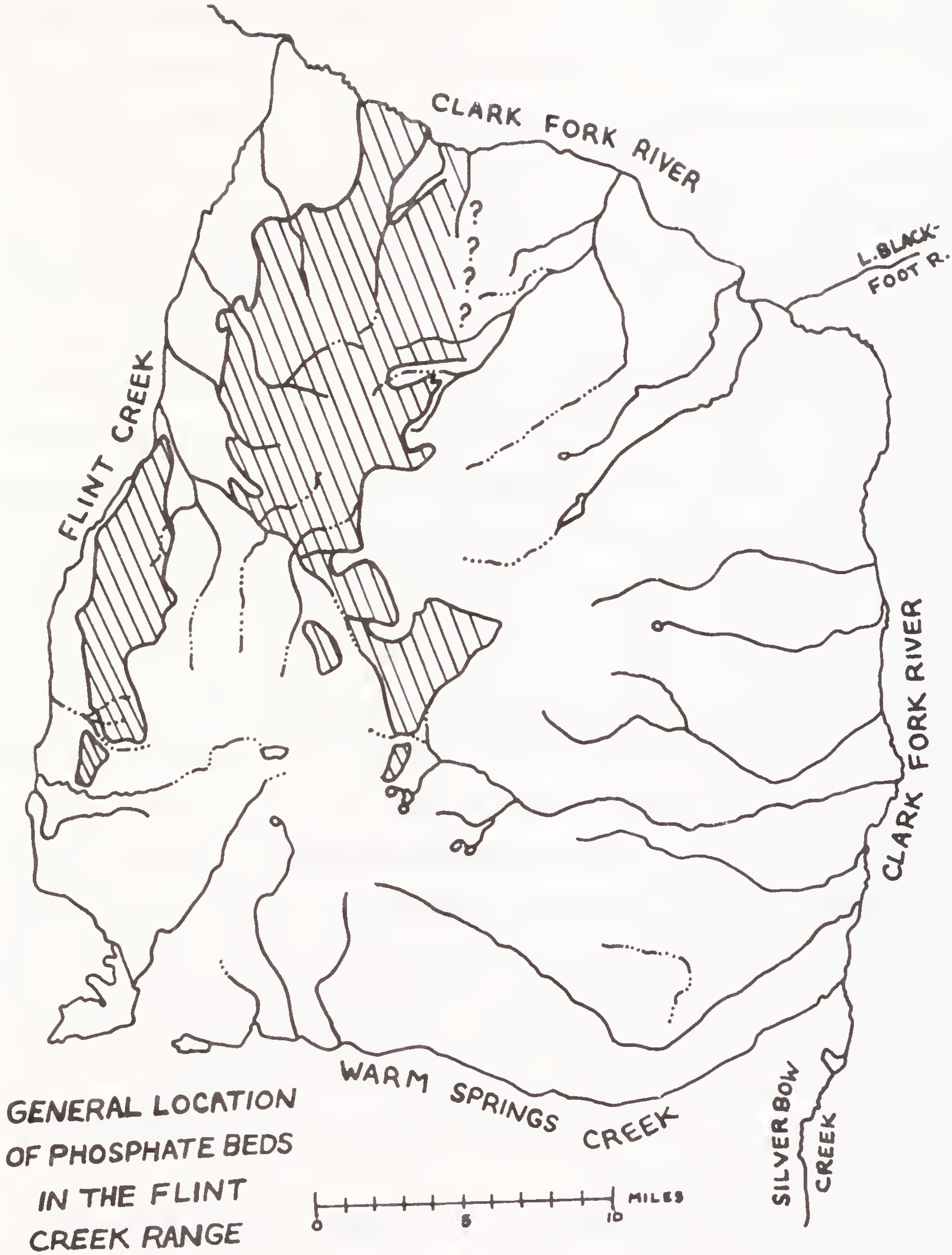

CLARK FORK RIVER
L. BLACK-FOOT R.
FLINT CREEK
CLARK FORK RIVER
WARM SPRINGS CREEK
SILVER BOW CREEK
GENERAL LOCATION OF PHOSPHATE BEDS IN THE FLINT CREEK RANGE
0
5
10
MILES

Figure 6

genera of macroscopic algae and a thin coating of diatoms covering the rocky substrate. Four major groups of algae were represented, including 21 genera of nondiatom algae (Appendix 1). Diatoms were by far the most common algae, followed by the blue-green algae Phormidium and Nostoc and the red algae Audouinella and Hildenbrandtia. The green algae group was represented by 12 genera, none of which occurred at more than seven sites. Macrophytes (higher plants) were not common.

The diatom associations in streams of the Flint Creek Range contained 38 genera and at least 245 distinct taxa (Appendix 2). Many taxa could not be identified with available keys. Achnanthes minutissima was by far the most abundant diatom, accounting for 23.7 percent of all cells counted and found at all but one of the stations sampled. Other common species were Diatoma hiemale, Achnanthes lanceolata, Navicula minima, Fragilaria construens and Cocconeis placentula. Diatom community information contained in Table 3 was used for a preliminary screening of stations exhibiting biological stress. Samples with less than 25 taxa counted and/or with diversity ($\bar{d}$) values less than 3 were suspect. Those with either low taxa counted or low diversity, but not both, were considered questionably stressed. It is important to reiterate that biological "stress" may be caused by natural as well as cultural factors, for example, by consistently low water temperature. Seventeen of the fifty stream stations sampled exhibited either a depressed diatom diversity or fewer than 25 diatom taxa. However, only ten stations showed both a depressed diversity and number of taxa, and of these ten, in only five cases could this biological data be correlated directly with chemical, physical or field evidence of impacts to the aquatic habitat. Therefore, it was assumed that the suggested biological stress, in many instances, was either natural in origin or questionable.

With very few exceptions, the present relative abundance (PRA) of Achnanthes species was well in excess of the PRA of Nitzschia species in streams draining the Flint Creek Range (Table 3). This consistent relationship indicates waters generally

rich in dissolved oxygen and low in organic, especially nitrogenous, enrichment. Other features of the algal flora pointed to cold, slightly alkaline waters of low to moderate conductivity, firm, stable substrates and occasional enrichment with inorganic phosphorus.

Field Surveys

Field investigations usually pinpointed the actual sources of pollution which were detectable by water and biological analysis of samples collected at the stream stations. Frequently, the sources were quite obvious, as in the case of the Wasa Mine tailings and the Douglas Creek tailings above Philipsburg. In some instances the field surveys identified actual or potential water quality problems which were not documented by sample analysis. This almost always involved sedimentation problems, such as those observed at Gold and Princeton Creeks. It is expected that these types of problems would be more severe during periods of runoff and higher stream flow and at such times would be detectable by the other water quality measurements used in this study. In addition to problem areas, field surveys identified numerous mine seeps which were shown, through field determinations, to pose no threat of surface water pollution.

In Table 4, stream stations identified as being impacted to at least a minor degree and the apparent causes of the problems are summarized. These assessments were based on the collective results of the investigation, including chemical, physical and biological parameters as well as indicators of field surveys.

One group of parameters was not considered as conclusive evidence of impact. For example, streams which showed slightly elevated metals levels but failed to exhibit biological or other stress may have been rated as receiving only minor stress since it seemed apparent that the metals contributions were effectively buffered by the chemical and physical characteristics of the receiving stream. On the other hand, a stream having no physical or chemical indications of impact but revealing a depressed

periphyton community may have been rated as questionably stressed. This decision was based on the fact that periphyton organisms have a generation time of only a few days or less and except for longer lived algal species, reflect conditions prevailing just prior to the time of collection. Therefore, the periphyton association may have been indicating past or intermittent problems which were not readily detectable by other tests during the time of actual sample collection. The possibility of errors in sample collection, handling or analysis were also considered, although the greatest care was taken to prevent problems of this type.

VII Conclusions

Contrary to the original expectations of the authors, few positively identifiable cases of mining-related surface water quality degradation were observed in the Flint Creek Range in the period from June to September, 1978. Tributary streams draining the range were generally of good to excellent quality, cold and highly oxygenated, with low to moderate conductivity and slightly alkaline waters containing low concentrations of heavy metals and suspended solids and an abundance and diversity of aquatic flora and fauna.

Although the overall incidence of unquestionably stressed streams was low, the impacted stream stations which were identified could usually be related to mining activity. Conversely, streams showing the highest water quality usually occurred in areas of less extensive prospecting. Only two tributaries found to be impacted by mining were rated as severely stressed: the North Fork of Douglas Creek and the other Douglas Creek in the Philipsburg area. In both cases, degradation resulted from the creek waters contacting tailings dumps and it was expressed in the form of elevated sulfate, cadmium, copper, iron and zinc concentrations and a severe reduction in numbers and kinds of aquatic organisms. Fortunately enough, both streams contained very low volume flows and any impacts contributed to larger-order streams were very marginal. A small groundwater seep flowing through a washed out tailings pond on

upper Boulder Creek was also found to be of very poor quality due to contact with mine tailings but effects to Boulder Creek below its confluence were not detectable. Other stream segments found to be impacted to lesser degrees by mining were portions of Dunkelberg, Fred Burr, Cable, Camp and Princeton Creeks.

Several drainages of the range showed total phosphorus concentrations above those normally expected in mountain headwaters regions. There seemed to be some correlation between the occurrence of these elevated levels and the location of phosphate beds of the Phosphoria Formation. No evidence was found that mining had contributed in any way to the levels observed, but at two stations, agricultural practices were suspect.

Potential sources of water quality degradation, in the form of critical sediment sources, were found at several locations during the study. Active and abandoned placer operations on Princeton and Gold Creeks, and perhaps others which were not observed had the capability it was felt, to contribute significant sediment loads to nearby waterways during periods of runoff. The placer tailings on upper and lower Gold Creek were especially extensive.

VIII Recommendations

The authors feel that most hardrock mining-related problem areas identified in the Flint Creek Range by this study are not of sufficient magnitude to warrant the very costly reclamation measures that would be necessary to realize substantial improvements in water quality. Most significant problems occurred on very small-order streams and effects were noticeable for short distances only. These recommendations are based on conditions that were found to be present in the summer (1978) season. If subsequent investigators determine that a much different situation exists during spring runoff, a reevaluation would be necessary. This, however, is thought not to be the case.

Potential problem areas related to certain active and abandoned placer operations

in the range may warrant some form of reclamation. Reducing the threat of sedimentation to streams from recent placer diggings, especially in upper Gold Creek, might necessitate grading to reduce slope angle and revegetation of denuded surfaces to hold sediments in place. Damage to lower Gold Creek from the extensive historical placer mining that has taken place there is probably on the decline. The tailings would probably be best left to continue revegetating naturally. The same is true for lower Princeton Creek in the Boulder Creek drainage where extensive historic placer mining has left an unstable stream channel of very large rubble. Recent small placer operations on upper Princeton Creek near the Moonlight Mine are confined to an area along and in the stream channel. They pose a threat of sedimentation and corrective action should be taken. Other placer operations on streams draining the range (most of which are abandoned) are extremely numerous. However, they generally are located on the lower lengths of the streams due to the extreme size of stream bed material in the upper reaches and thus fall outside of the arbitrary boundaries chosen for the study area. As such, problems relating to them have not been addressed in this report.

Numerous active small miner operations occur in the Flint Creek Range and most likely will, with increasing metals prices, become more numerous in the future. It is nearly a certainty that some of these will pose threats to the existing high-quality water found throughout much of the range. Locations of many current operations are now known, but new activities and expansion of the existing ones will occur without the awareness of water quality managers. Surveillance of these operations on a periodic basis to help prevent problems before they occur would be desirable, but usually is not practical. Small miners (those moving not in excess of 36,500 tons of material in one calendar year) are required to obtain a license from the Montana Department of State Lands (DSL) under the New Hard Rock Law, Title 50, Chapter 12 of the Revised Codes of Montana (1947) and annually agree in writing that they will not

pollute or contaminate any stream. The DSL, therefore, is constantly aware of the activities and developments of such operations. It would seem a simple matter for the Hard Rock Bureau of DSL to refer potential or actual water quality problems to the Water Quality Bureau (WQB) for corrective action. Section 21 of the New Hard Rock Law, however, provides for confidentiality of information between miners and DSL. If a small miner pollutes or contaminates a stream, he is in violation of the hard rock law and the confidentiality clause can be breached. But, the Hard Rock Bureau is nonetheless hesitant to make such referrals due to staff liability and the potential for breach of confidentiality should the violation be challenged in court. Further, the Hard Rock Bureau does not feel it should be duplicating the functions of the WQB by monitoring water quality problems created by small miners. The only other information source available to the WQB concerning these types of problems are citizens complaints. In light of these circumstances, it would be very beneficial to the protection of State waters to:

1) Amend Section 21 of the New Hard Rock Law to include the Department of Health and Environmental Sciences, or otherwise alter the confidentiality provision so that suspected violations can legally be referred to the WQB.

or

2) Have the DSL more actively enforce the pollution provisions under the Hard Rock Act. This would include routine surveillance and monitoring of small mining operations and actively seeking corrective action and/or penalties in applicable situations. Analytical services by the Department of Health lab are currently available for pollution investigations at no cost to the DSL.

3) More actively educate and advise small miners on water pollution prevention related to their mining activities. This could be a joint undertaking by both the WQB and the DSL.

Increased use of the Flint Creek Range, be it related to mining, timber harvesting or recreation, is inevitable. Most of the range consists of U.S. Forest Service land, falling within the Deer Lodge and Philipsburg Ranger Districts. An agreement will soon be enacted between the USFS and the WQB concerning prevention of nonpoint source pollution on USFS lands. The emphasis of the agreement is to anticipate and avoid problems relating to USFS activities (such as timber sales, road and bridge construction and various construction projects) before they occur. The WQB will review projects of concern and work with the USFS to resolve any problems which may lead to water quality degradation. Since mining on both large and small scales and associated activities such as road building and construction frequently occur on or near USFS lands, the authors hope that cooperative efforts between the WQB and USFS to prevent water pollution can be extended to these activities.

Table 4 Summary - Impacted stream stations in drainages of the Flint Creek Range.

Stream Station and Number	Evidence of Impact: Chemical	Evidence of Impact: Biological	Evidence of Impact: Physical	Evidence of Impact: Field Observations	Source	Degree
Barnes Creek near mouth (1)	High total phosphorus, iron, elevated sulfate levels.	Low PRA Achnanthes species possibly due to unstable substrate.	High TSS, TDS.	Sediment blanketing stream bottom.	Agricultural practices suspected.	Moderate.
Douglas Creek below seep from adit (3)	Marginally high silver, zinc levels.	No indications of impact	No indications of impact.	No indications of impact.	Wasa Mine tailings.	Minor.
Seep from adit to Douglas Creek (4)	No indications.	Depressed diatom diversity ($\bar{d}$), number of taxa.	No indications.	No indications.	Unknown. May be natural.	Questionable.
Douglas Creek below confluence North and Middle Forks (5)	Marginally high zinc levels.	No indications.	No indications.	No indications.	Wasa Mine tailings.	Minor.
North Fork Douglas Creek at mouth (6)	Elevated cadmium, zinc levels.	Slightly depressed diatom $\bar{d}$.	No indications.	No indications.	Wasa Mine tailings.	Minor to moderate.
North Fork Douglas Creek .5 mile below Wasa Mine (7)	Elevated sulfate, high cadmium, zinc levels.	Severely depressed diatom $\bar{d}$, number of diatom taxa, invertebrates absent.	Sediment.	Yellow boy present on stream bottom.	Wasa Mine tailings.	Severe.
North Fork Douglas Creek just below Wasa Mine (8)	Elevated sulfate, cadmium, copper, iron, zinc levels.	Severely depressed diatom $\bar{d}$, number of diatom taxa, invertebrates absent.	Sediment.	Yellow boy present.	Wasa Mine tailings.	Severe.
Middle Fork Douglas Creek at mouth (9)	No indications.	Depressed diatom -d, number of diatom taxa	No indications.	No indications.	Unknown. May be natural.	Questionable.
Seep from adit above Middle Fork Douglas Creek (10)	No indications.	Severely depressed diatom $\bar{d}$, number of diatom taxa.	No indications.	No indications.	Unknown. May be natural.	Questionable.
Princeton Creek near mouth (15)	No indications.	No indications.	No indications.	Sediment blanketing stream bottom, sedimentation potential.	Placer tailings from Moonlight Mine area downstream to mouth.	Minor.
Royal Gold Creek near mouth (18)	Marginally high zinc, cadmium levels.	Invertebrate numbers slightly depressed.	No indications.	No indications.	Unknown.	Minor.

Table 4 continued.

Stream Station and Number	Evidence of Impact: Chemical	Biological	Physical	Field Observations	Source	Degree
Seep from tailings pond to Boulder Creek (20)	Marginally high cadmium, copper, lead, high iron, zinc levels.	Not sampled for periphyton, invertebrate numbers depressed.	No indications.	Some sediment blanketing stream bottom.	Tailings pond.	Moderate to severe.
Granite Creek near mouth (23)	Marginally high zinc levels.	Slightly depressed diatom $\bar{d}$.	No indications.	No indications.	Unknown.	Very minor.
Camp Creek above Philipsburg (24)	Elevated sulfate, zinc levels.	Depressed diatom $\bar{d}$.	No indications.	No indications.	Unknown - assumed to be abandoned mines in drainage.	Minor to moderate.
Douglas Creek below tailings at Philipsburg (25)	Elevated sulfate, cadmium, copper, iron, manganese, zinc levels somewhat depressed pH.	Depressed diatom $\bar{d}$, severely depressed number of diatom taxa, no invertebrates.	No indications.	Sediment blanketing stream bottom.	Tailings, tailings pond.	Severe.
Fred Burr Creek below Rumsey (26)	No indications.	Severely depressed diatom $\bar{d}$, depressed number of diatom taxa.	No indications.	Sediment blanketing stream bottom.	Rumsey Mill.	Moderate.
Fred Burr Creek above Rumsey (27)	No indications.	Depressed diatom $\bar{d}$.	No indications.	No indications.	Unknown. May be natural.	Questionable.
North Fork Flint Creek below Golden Jubilee Mine (30)	No indications.	Depressed diatom $\bar{d}$ from stations above and below.	No indications.	No indications.	Unknown. May be natural.	Questionable.
Cable Creek near mouth (32)	No indications.	Slightly depressed diatom $\bar{d}$.	No indications.	Sediment blanketing stream bottom.	Tailings, tailings pond below Cable Mine.	Minor.
West tributary Cable Creek below Cable Mine (33)	No indications.	No indications.	No indications.	Sediment blanketing stream bottom.	Tailings, tailings pond below Cable Mine.	Minor.
Antelope Creek above mouth (38)	Marginally high silver, iron, very high total phosphorus.	No indications.	No indications.	Sediment blanketing stream bottom.	Phosphorus, sediment possibly agricultural in origin, metals may be normal background.	Minor.
Gold Creek below Master Mine (47)	No indications.	Depressed diatom $\bar{d}$, number of diatom taxa.	No indications.	Sedimentation potential.	Biological indications may be due to natural cause. Sedimentation potential due to placer tailings.	Moderate.

Table 4 continued.

Stream Station and Number	Evidence of Impact: Chemical	Biological	Physical	Field Observations	Source	Degree
Pikes Peak Creek below mine seep (48)	No indications.	Depressed diatom $\bar{d}$.	No indications.	No indications.	Unknown. May be natural.	Questionable.
Seep from adit above upper Pikes Peak Creek (49)	No indications.	Severely depressed diatom $\bar{d}$, number of diatom taxa.	No indications.	No indications.	Unknown. May be natural.	Questionable.
Dunkelberg Creek near mouth (50)	Marginally high iron, zinc levels. Relatively high total phosphorus levels.	Depressed diatom $\bar{d}$. High PRA *Nitzschia* species.	No indications.	No indications.	Apparent nitrogen enrichment from unknown source.	Minor to moderate.
Dunkelberg Creek below Forest Rose Mine (51)	Elevated sulfate, zinc levels.	Depressed diatom $\bar{d}$, slightly depressed number diatom taxa. Depressed invertebrate community.	No indications.	No indications.	Forest Rose Mine tailings, partially thermal or natural stress.	Minor to moderate.

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Appendix 1. Percent occurrence of diatoms and non-diatom algal genera in streams draining the Flint Creek Range.

CHLOROPHYTA (Green Algae)	
Chaetophora	4
Cladophora	8
Closterium	14
Microspora	6
Mougeotia	6
Oedogonium	4
Rhizoclonium	2
Spirogyra	10
Stigeoclonium	4
Tetraspora	12
Ulothrix	10
Zygnema	4
CHRYSOPHYTA (Golden-Brown Algae)	
Diatoms (Bacillariophyceae)	100
Hydrurus	12
Tribonema	6
Vaucheria	12
CYANOPHYTA (Blue-Green Algae)	
Nostoc	28
Oscillatoria	8
Phormidium	36
Tolypothrix	12
RHODOPHYTA (Red Algae)	
Audouinella	18
Hildenbrandtia	18

Appendix 2. Mean percent relative abundance and percent **occurrence of** diatom taxa inhabiting streams draining the Flint Creek Range.

Taxon	Mean Abundance	Percent Occurrence
Achnanthes affinis Grun.	<0.1	2
A. austriaca Hust.	< 0.1	2
A. clevei Grun.	< 0.1	6
A. clevei var. rostrata Hust.	< 0.1	14
A. deflexa Reim.	< 0.1	6
A. exigua Grun.	< 0.1	10
A. exigua var. constricta (Grun.) Hust. ?	< 0.1	4
A. lanceolata (Breb.) Grun.	6.7	90
A. lanceolata var. dubia Grun.	0.3	32
A. lapponica var. ninckei (Guerm & Mang) Reim.	< 0.1	6
A. levanderi Hust.	< 0.1	2
A. lewisiana Patr.	0.3	12
A. linearis (W. Sm.) Grun. ?	0.4	34
A. linearis f. curta H. L. Sm.	< 0.1	4
A. linearis var. pusilla Grun.	< 0.1	2
A. microcephala (Kutz.) Grun.	< 0.1	2
A. minutissima Kutz.	23.7	98
A. peragalli Brun. & Herib.	< 0.1	6
A. peragalli var. parvula (Patr.) Reim. comb. nov.	< 0.1	2
A. pinnata Hust. ?	0.1	6
A. stewartii Patr. ?	< 0.1	2
A. wellsiae Reim. nom. nov.	< 0.1	2
A. sp.	0.2	26
Amphipleura pellucida Kutz.	0.1	10
Amphora ovalis (Kutz.) Kutz.	< 0.1	2
A. ovalis var. affinis (Kutz.) V. H. ex DeT.	0.1	8
A. ovalis var. pediculus (Kutz.) V. H.	< 0.1	4
A. perpusilla (Grun.) Grun.	1.8	66
A. submontana Hust. ?	< 0.1	8
A. sp.	< 0.1	4
Anomoeoneis serians var. brachysira (Breb. ex Kutz.) Hust.	< 0.1	4
A. vitrea (Grun.) Ross comb. nov.	< 0.1	2
A. sp. ?	0.1	2

Taxon	Mean Abundance	Percent Occurrence
Asterionella formosa Hass.	< 0.1	4
Caloneis alpestris (Grun.) Cl. ?	< 0.1	2
C. bacillum (Grun.) Cl.	0.4	42
C. hyalina Hust.	< 0.1	2
C. ventricosa (Ehr.) Meist.	< 0.1	4
C. ventricosa var. truncatula (Grun.) Meist. ?	< 0.1	2
C. sp.	< 0.1	12
Cocconeis diminuta Pant.	< 0.1	2
C. disculus (Schum.) Cl.	0.2	4
C. fluviatilis Wallace	< 0.1	12
C. pediculus Ehr.	0.4	12
C. placentula Ehr.	4.1	82
C. placentula var. euglypta (Ehr.) Cl.	X	X
Cyclotella comta (Ehr.) Kutz.	< 0.1	4
C. glomerata Bachmann	< 0.1	2
C. meneghiniana Kutz.	< 0.1	6
C. sp. ?	< 0.1	6
Cymatopleura solea (Breb. & Godey) W. Sm.	< 0.1	4
Cymbella affinis Kutz.	0.1	12
C. amphicephala Naeg.	< 0.1	2
C. angustata (W. Sm.) Cl. ?	< 0.1	2
C. brehmii Hust.	0.6	24
C. cistula (Ehr.) Kirchn.	< 0.1	8
C. cymbiformis var. nonpunctata Font.	0.2	10
C. delicatula Kutz.	< 0.1	2
C. diluviana (Krasske) Florin ?	0.1	14
C. lunata W. Sm.	< 0.1	2
C. microcephala Grun.	< 0.1	4
C. minuta Hilse ex Rabh.	1.2	70
C. naviculiformis (Auersw. ex Rabenh.) Kirchn.	< 0.1	2
C. prostrata (Berkeley) Cl.	< 0.1	2
C. prostrata var. auerswaldii (Rabh.) Reim. comb. nov.	< 0.1	6
C. sinuata Greg.	0.9	62
Denticula elegans Kutz.	< 0.1	4
D. sp.	< 0.1	4
Diatoma anceps (Ehr.) Kirchn.	< 0.1	10

Taxon	Mean Abundance	Percent Occurrence
Diatoma hiemale (Roth.) Heib.	2.1	42
D. hiemale var. mesodon (Ehr.) Grun.	6.0	76
D. vulgare Bory	< 0.1	4
Diatomella balfouriana Grev.	0.1	14
Didymosphenia geminata (Lyngb.) M. Schmidt	0.1	6
Diploneis oblongella (Naeg. ex Kutz.) Ross	< 0.1	2
D. ostracodarum (Pant.) Jur.	< 0.1	2
D. puella (Schum.) Cl.	< 0.1	6
Epithemia adnata (Kutz.) Breb.	< 0.1	2
E. emarginata Andrews	< 0.1	2
E. turgida (Ehr.) Kutz.	0.1	18
E. sp.	< 0.1	8
Eunotia curvata (Kutz.) Lagerst.	< 0.1	4
E. maior (W. Sm.) Rabh. ?	< 0.1	4
E. pectinalis var. minor (Kutz.) Rabh.	< 0.1	2
E. perpusilla Grun. ?	< 0.1	2
E. praerupta Ehr.	< 0.1	2
E. tenella (Grun.) Cl.	0.1	12
E. sp.	0.1	24
Fragilaria bicapitata A. Mayer	< 0.1	2
F. brevistriata Grun.	0.7	26
F. capucina var. mesolepta Rabh.	< 0.1	2
F. construens (Ehr.) Grun.	0.5	42
F. construens var. binodis (Ehr.) Grun.	< 0.1	4
F. construens var. pumila Grun.	< 0.1	4
F. construens var. venter (Ehr.) Grun.	6.2	64
F. crotonensis Kitton.	< 0.1	8
F. leptostauron (Ehr.) Hust.	0.3	18
F. leptostauron var. dubia (Grun.) Hust.	1.3	40
F. pinnata Ehr. ?	0.1	10
F. pinnata var. intercedens (Grun.) Hust.	< 0.1	2
F. vaucheriae (Kutz.) Peters	1.5	64
F. vaucheriae var. capitellata (Grun.) Peters	0.4	12
F. virescens Ralfs.	< 0.1	2
F. sp.	0.1	6

Taxon	Mean Abundance	Percent Occurrence
Frustulia rhomboides (Ehr.) de Toni	< 0.1	4
F. rhomboides var. amphipleuroides (Grun.) Cl.	< 0.1	10
F. vulgaris (Thwaites) DeT.	< 0.1	12
F. sp.	< 0.1	2
Gomphoneis herculeana (Ehr.) Cl.	< 0.1	4
Gomphonema affine Kutz.	< 0.1	4
G. angustatum (Kutz.) Rabh.	1.5	54
G. angustatum var. citera (Hohn & Hellerm.) Patr. comb. nov.	0.2	10
G. bohemicum Reichelt et Fricke	< 0.1	4
G. clevei Fricke	< 0.1	4
G. dichotomum Kutz. ?	0.1	6
G. instabilis Hohn & Hellerm.	< 0.1	2
G. intricatum Kutz.	0.2	12
G. longiceps f. gracilis Hust. ?	0.1	2
G. olivaceoides Hust.	1.5	14
G. olivaceum (Lyngb.) Kutz.	< 0.1	8
G. parvulum Kutz.	0.4	30
G. quadripunctatum (Østr.) Wisl.	0.7	10
G. subclavatum var. commutatum (Grun.) A. Mayer ?	< 0.1	4
G. subclavatum var. mexicanum (Grun.) Patr.	< 0.1	4
G. tenellum Kutz. ?	0.4	12
G. truncatum Ehr.	< 0.1	4
G. sp.	1.5	50
Gyrosigma spencerii (Quek.) Griff. & Henfr.	< 0.1	2
G. spencerii var. curvula (Grun.) Reim. comb. nov.	< 0.1	2
Hannaea arcus (Ehr.) Patr.	1.8	44
Hantzschia amphioxys (Ehr.) Grun.	0.1	18
Melosira distans (Ehr.) Kutz.	1.5	46
M. granulata (Ehr.) Ralfs. ?	< 0.1	4
M. italica (Ehr.) Kutz.	0.2	14
M. varians Ag.	0.1	12
M. sp.	< 0.1	2
Meridion circulare (Grev.) Ag.	1.0	62
M. circulare var. constrictum (Ralfs.) V. H.	< 0.1	4
Navicula accomoda Hust.	< 0.1	2
N. amphipleuroides Hust. ?	< 0.1	2

Taxon	Mean Abundance	Percent Occurrence
Navicula anglica var. subsalsa (Grun.) Cl.	< 0.1	2
N. arvensis Hust.	0.8	58
N. atomus (Kutz.) Grun. ?	< 0.1	6
N. bacillum Ehr.	< 0.1	2
N. capitata Ehr.	< 0.1	2
N. cascadensis Sov.	0.1	6
N. cincta (Ehr.) Ralfs.	< 0.1	2
N. cincta var. rostrata Reim.	< 0.1	4
N. contenta f. biceps (Arnott) Grun.	< 0.1	2
N. cryptocephala Kutz.	0.1	10
N. cryptocephala var. veneta (Kutz.) Rabh.	0.8	54
N. digna Hust.	< 0.1	2
N. disjuncta Hust.	< 0.1	2
N. festiva Krasske ?	< 0.1	2
N. gottlandica Grun.	< 0.1	4
N. graciloides A. Mayer	< 0.1	4
N. heufleri Grun. ?	< 0.1	10
N. heufleri var. leptocephala (Breb. & Grun.) Patr.	< 0.1	2
N. ingrata Krasske	< 0.1	2
N. laevissima Kutz.	< 0.1	4
N. lamii Manguin	0.9	36
N. lanceolata (Ag.) Kutz.	< 0.1	6
N. menisculus var. upsaliensis (Grun. in Cl. & Grun.) Grun.	0.2	16
N. minima Grun.	6.4	86
N. mutica Kutz.	< 0.1	8
N. notha Wallace	0.2	22
N. oblonga (Kutz.) Kutz.	< 0.1	2
N. peregrina (Ehr.) Kutz. ?	< 0.1	2
N. perparva Hust.	0.1	10
N. perpusilla (Kutz.) Grun. ?	< 0.1	12
N. pseudoreinhardtii Patr.	0.2	2
N. pseudoscutiformis Hust.	< 0.1	4
N. pupula Kutz.	< 0.1	4
N. pupula var. elliptica Hust. ?	< 0.1	4
N. radiosa Kutz.	< 0.1	12
N. radiosa var. parva Wallace	0.7	58

Taxon	Mean Abundance	Percent Occurrence
Navicula radiosa var. tenella (Breb. & Kutz.) Grun.	< 0.1	2
N. reinhardtii (Grun.) Grun.	< 0.1	2
N. rhynchocephala Kutz.	< 0.1	2
N. rotaeana (Rabh.) Grun.	< 0.1	10
N. secreta var. apiculata Patr.	0.2	20
N. seminulum Grun.	0.1	12
N. seminulum var. hustedtii Patr.	< 0.1	2
N. tenelloides Hust. ?	< 0.1	2
N. tongatensis Hust. ?	0.2	14
N. tripunctata (O. F. Mull.) Bory	2.2	38
N. vanheurckii Patr. sp. nov. ?	< 0.1	2
N. variostriata Krasske	< 0.1	2
N. viridula (Kutz.) Kutz.	< 0.1	2
N. viridula var. avenacea (Breb. & Grun.) V. H.	0.3	16
N. viridula var. rostellata (Kutz.?) Cl.	< 0.1	2
N. sp.	0.4	52
Neidium iridis (Ehr.) Cl.	< 0.1	2
Nitzschia acicularis (Kutz.) W. Sm.	0.1	6
N. amphibia Grun.	< 0.1	10
N. capitellata Hust.	0.1	12
N. communis Rabh.	< 0.1	14
N. denticula Grun.	< 0.1	2
N. dissipata (Kutz.) Grun.	1.6	74
N. epiphytica O. Mull.	1.6	22
N. filiformis (W. Sm.) Hust.	< 0.1	2
N. frustulum Kutz.	0.7	58
N. frustulum var. subsalina Hust.	0.2	28
N. gracilis Hantz.	0.1	18
N. hantzschiana Rabh.	0.1	14
N. ignorata Krasske ?	< 0.1	10
N. kutzingiana Hilse	< 0.1	8
N. linearis (Ag. ex W. Sm.) W. Sm.	0.7	56
N. microcephala Grun.	0.1	20
N. palea (Kutz.) W. Sm.	0.6	44
N. paleacea Grun.	0.3	34
N. recta Hantz.	< 0.1	6

Taxon	Mean Abundance	Percent Occurrence
Nitzschia romana Grun.	0.1	18
N. sigmoidea (Ehr.) W. Sm.	< 0.1	4
N. sublinearis Hust.	< 0.1	2
N. vermicularis (Kutz.) Hant.	< 0.1	2
N. sp.	< 0.1	12
Opephora martyi Herib.	< 0.1	4
Pinnularia borealis Ehr.	< 0.1	12
P. braunii var. amphicephala (A. Mayer) Hust.	< 0.1	2
P. maior (Kutz.) Rabh.	< 0.1	2
P. mesolepta var. angusta Cl.	0.1	6
P. viridis var. commutata (Grun.) Cl.	< 0.1	2
P. sp.	0.1	22
Rhoicosphenia curvata (Kutz.) Grun.	0.6	48
Rhopalodia gibba (Ehr.) O. Mull.	< 0.1	10
R. gibba var. ventricosa (Kutz.) H. & M. Perag.	0.1	2
R. musculus (Kutz.) O. Mull.	< 0.1	2
Stauroneis kriegeri Patr.	< 0.1	2
S. phoenicenteron f. gracilis (Ehr.) Hust.	< 0.1	2
S. smithii Grun.	< 0.1	6
Stephanodiscus hantzschii Grun.	< 0.1	4
S. minutus Cl. & Moll.	0.2	6
Surirella angustata Kutz.	0.4	24
S. ovalis Breb.	< 0.1	2
S. ovata Kutz.	0.5	26
Synedra acus Kutz.	< 0.1	4
S. mazamaensis Sov.	< 0.1	2
S. parasitica (W. Sm.) Hust.	< 0.1	4
S. rumpens Kutz.	0.9	52
S. ulna (Nitz.) Ehr.	0.5	22
S. ulna var. contracta Østr.	1.2	28
S. ulna var. ramesi (Herib.) Hust.	0.1	8
S. sp.	< 0.1	6
Tabellaria flocculosa (Roth) Kutz.	< 0.1	4

? Tentative identification

X Included with nominate variety

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